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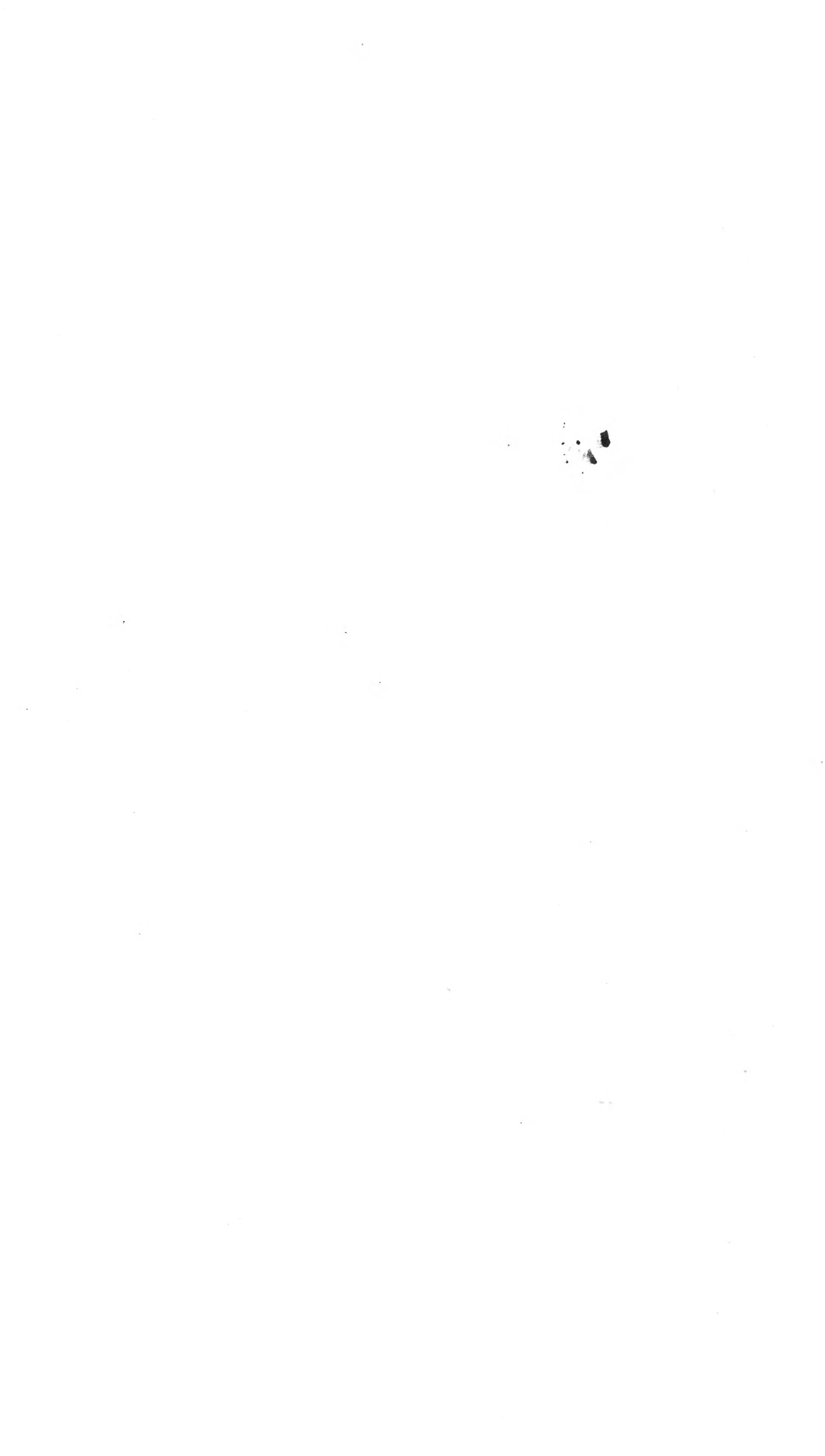
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[PROC. ROY. SOC. VICTORIA, 57 (N.S.), Pts. I-II., 1945.]

ART I.—*The Geology of Phillip Island.*

By A. B. EDWARDS, D.Sc.

[Read 13th July, 1944; issued separately 10th December, 1945.]

Abstract.

Phillip Island, which lies across the mouth of Western Port Bay, consists of a large central island, to which is tied a number of smaller islands at both its south-eastern and south-western extremities. It represents the south-eastern interfluvium of the river that was drowned to form Western Port Bay. The land slopes gently northwards, and there are few permanent streams. High cliffs occur along the exposed southern coast, while the low northern coastline, in the shelter of Western Port Bay, is prograding. The island consists essentially of a number of flows of Tertiary Older Volcanic basalts, intercalated with thick beds of ochreous red tuff and agglomerate, and overlying Jurassic and Palaeozoic sediments and Palaeozoic granites.

Introduction.

Phillip Island, which lies across the mouth of Western Port Bay, is 13 miles long and $5\frac{1}{2}$ miles wide at its widest point. It has an area of about 60 square miles. On the eastern side it is separated from the San Remo Peninsula by the narrow Eastern Passage, which is from $\frac{1}{4}$ to $\frac{3}{4}$ of a mile wide, and has a maximum depth of about 30 feet. On the western side it is separated from the Mornington Peninsula by the Western Passage, which is from $2\frac{1}{2}$ to 6 miles wide, and has a maximum depth of 90 feet. These two channels separating the island from the mainland are the drowned valleys of streams which were either overdeepened during a low sea-level period of the Pleistocene Ice Age or submerged as a result of subsidence during the Quaternary. The island represents the southern interfluvium of the old Western Port River. The tidal range at Cowes, on the northern coast of the island, varies from $7\frac{1}{2}$ feet at neap tides to 12 feet at spring tides, and the tidal race through the Passages develops a maximum velocity of 6 miles an hour.

COMPOSITE STRUCTURE.

As shown in fig. 1, Phillip Island is a composite island. It consists of a large central island, to which is tied a number of smaller islands.

The narrow south-western extremity of the present island consists of two small tied islands, here called Phelan's Island and Summerland's Island, and The Knobby. Phelan's Island and Summerland's Island are joined to the main island by a Y-shaped

tombolo which encloses the partly silted-up fresh-water lagoon of Swan Lake. The Knobby is connected to Summerland's Island by a storm-wave platform that is covered at high tide (Pl. I., fig. 1). About $\frac{1}{2}$ mile to sea, south-west from the Knobby, is a further small island, Seal Rocks (Pl. I., fig. 1). The submarine contours show that it is an integral member of this group of small islands (fig. 1). They are all composed of a series of basalt flows from 20 to 30 feet thick, separated by thin red beds of tuff or weathered basalt (flow tops) along which erosion is concentrated. The lava-flows lie almost horizontal, but the surface of Summerland's Island slopes evenly to the north-west. This series of islands is part of the ridge forming the south-eastern interfluvium of the old Western Port River, and the passages between them represent the valleys of small streams tributary to this river. The valleys between Phelan's Island, Summerland's Island, and the main island were first drowned, and then silted up, following the growth of bars across both ends of the channel. The valley between The Knobby and Summerland's Island was left as a low level tract more subject to wave erosion than the higher land to the north-east and south-west. Erosion was concentrated along a red band between the tide levels.

The valley between Seal Rocks and The Knobby is too deeply drowned to permit the growth of spits in such exposed water.

The narrow south-eastern extremity of Phillip Island also consists of a group of small islands tied to one another and to the main island. The most prominent of these tied islands is that formed by the Cape Woolamai granite stock which is linked to the main island by a tie-bar $\frac{1}{2}$ mile wide, carrying sand dunes over 100 feet high (Hills, 1940, p. 229). The inner tied islands are rounded tops of low basaltic hills that rise only 50 feet above sea-level, and represent the higher land between a series of small valleys, some of which were tributary to the Eastern Passage, and some to the drowned Western Port river system.

Topography.

The island has a gently undulating surface, with a general slope to the north, so that whereas the cliffs along the southern coast rise to heights of 150 feet, those along the northern coast are only about 20 feet high. The highest point of the island, apart from Cape Woolamai (300 feet), is Quoin Hill (250 feet), a volcanic plug about 1 mile north-east of Swan Lake. Only four other points, Black Hill on the Ventnor-Knobby road, Richardson Hill in the centre of the island, the adjacent hill in allotment 54, and the hill to the south-east of Quoin Hill rise to 200 feet above sea level. A water parting extends from Quoin Hill to Rhyll.

In the interior of the island, the valleys are shallow swampy depressions trending chiefly to the north or north-west (fig. 1). Near the coast, the valleys become more pronounced, and the valley slopes are sometimes steep, particularly along the south coast. The only permanent stream, the Native Dog Creek, is short and flows into Bass Strait between Helen's Head and Red-cliff Head, through a gorge about 150 feet deep.

WATER SUPPLY.

Water supply is a serious problem on the island. The rainfall is about 30 inches a year, distributed as shown in Table I.

TABLE I.—AVERAGE MONTHLY RAINFALL.

				Points.
January	..	..	..	194
February	..	..	..	154
March	..	..	..	247
April	..	..	..	258
May	..	..	..	292
June	..	..	..	320
July	..	..	..	280
August	..	..	..	287
September	..	..	..	287
October	..	..	..	262
November	..	..	..	218
December	..	..	..	206

Potable water is available from shallow wells along the back-shore near Cowes township, and most of the local supply is pumped from these wells. The water lies at depths of from 5 to 10 feet, and the water level fluctuates with the tides, owing to the banking up of the seepage at high tides. The water is hard and somewhat saline as is indicated by the analyses Nos. 1 and 2, in Table 2, which were supplied by the courtesy of the Shire Secretary.

In the interior of the island, water is obtained from a number of wells and bores between 50 and 100 feet deep. The water is suitable for stock, but too mineralised for human consumption (Table 2, No. 4). It seeps down the columnar joints of the basalts and accumulates at the base of the basalt flows where they overlie more or less impervious tuff beds.

Springs occur at several localities. A spring of fresh water occurs on the northern side of the high sand dunes, in the reserve between allotments 148 and 151, in the narrow neck of land south of Swan Corner. The dunes overlie a thick bed of tuff, the surface of which slopes to the north. Rain water apparently percolates inland along this surface. Springs of mineralised water occur on the northern side of the Cape Woolamai granite, where the water has penetrated joint planes in the granite, and also close to Cape Woolamai itself (Blandowski, 1857, p. 56). Summerland's House in the south-west of the island obtains much of its water from a spring that issues on the northern side

of the tie-bar joining Summerland's Island to the main island. Mr. V. G. Anderson has kindly supplied an analysis of the water of this spring (Table 2, No. 3).

TABLE 2.—ANALYSIS OF WELL AND SPRING WATER, PHILLIP ISLAND.
(mg. per litre.)

		1	2	3	4
Ca	..	n.d.	n.d.	113	69
Mg	..	n.d.	n.d.	30	133
Na, K	..	70	45	136	819
Cl	..	100	65	234	1249
SO ₄	..	n.d.	n.d.	18	65
HCO ₃	..	n.d.	n.d.	478	355
NO ₃	..	.04	.86	.9	
SiO ₂	..	n.d.	n.d.	14	
Al ₂ O ₃	..	n.d.	n.d.	4	
Fe ₂ O ₃	..	n.d.	n.d.		11
Total Solids	..	470	340	1027.9	2701

1. Mathew's Well, Cowes, March, 1937.
2. University Camp Well, Cowes, March, 1937.
3. Water from Summerland's Spring, February, 1934.
4. Water at 117 ft., and rising to 100 ft., in Bore 8, allot. 13. (Rec. Boring Oper., 1926, p. 60).

The Coastlines.

The northern and southern coastlines present a striking contrast, partly owing to the marked difference in the strength of wave attack to which they are subjected, and partly owing to the northerly slope of the surface of the island, which greatly reduces the cliff height on the northern side.

THE SOUTHERN COASTLINE.

The southern coastline is exposed to the full violence of south-westerly gales sweeping across Bass Strait. It forms two large concave arcs, one on either side of the promontory leading out to Pyramid Rock, and consists of three sections of unequal length.

The western section, which is the longest, extends from The Knobby to near Sutherland's Bluff, where only a narrow neck of land, $\frac{3}{4}$ mile wide, separates Swan Corner from Bass Strait. This section consists of steep to sheer cliffs, 50 to 150 feet high (Pl. II., fig. 1), broken at irregular intervals by short stretches of sandy beach. The cliffs are cut in basalt and in thick beds of tuff and agglomerate. The steeper cliffs are cut in the basalts and as many as five successive flows of basalt, more or less horizontal, are exposed in the cliff faces, and stormwave platforms at their bases (Pl. I., fig. 1). In places, the uppermost lava-flow has been so eroded as to form an amphitheatre-like depression in the cliff tops (Pl. I., fig. 6). These depressions are not related to drainage lines, and it is difficult to explain their origin.

The almost vertical black cliffs in the basalt contrast strongly with the higher, less steep cliffs in the bright red-brown tuffs and agglomerate. The tuffs and agglomerates only occur at intervals—namely, at Phelan's Bluff, Redcliff Head, Smith's Bluff, Sutherland's Bluff, and at Forrest Caves and the unnamed bluff west of it. At each locality the tuff or agglomerate overlies more resistant basalt flows, which, at Phelan's Bluff and Redcliff Head, form the base of the cliffs for 10 to 20 feet above high tide level. At Phelan's Bluff, the tuff has been cut back so far that it is now beyond the reach of all but the largest waves and is faced with a boulder beach. The resulting double storm-wave platform at first sight suggests a recent coastal emergence of 14 feet (Pl. II., fig. 3).

All the headlands, and any straight sections of cliffs are fronted by storm-wave platforms (Edwards, 1941). These become narrow on the sides of the headlands, and in the smaller inlets they give place to steep boulder beaches, while in the larger inlets they give place to sandy beaches. The platforms are covered at high tide. They tend to be widest where the cliffs are relatively low, and grow narrower as the cliff height increases. The widest platforms are in the vicinity of Smith's Beach, where they are up to 300 feet wide. The surface of a platform frequently coincides with the top of a horizontal basalt flow (Pl. I., figs. 3 and 4). The tops of the flows are commonly marked by a red band of decomposed rock or tuff, from a few inches to a foot or more in thickness. The red band is less resistant to wave attack than the overlying columnar basalt, which is readily sapped. The surface of the resulting platform is generally level (Pl. I., fig. 4), but it sometimes shows an abrupt "step-up" in level (Pl. I., figs. 1, 4). This results from the columnar structure of the basalt flow above the red band. The basalt generally consists of an upper layer of columns with closely spaced horizontal joints and a base of broad stumpy columns with few horizontal joints (Pl. I., fig. 3). The junction of the two sets is a plane of weakness, and the wave attack may be more effective in eroding the upper layer of closely jointed columns than in sapping the whole thickness of the flow. Where this has happened, the platform "steps up" the height of the lower columns (Pl. I., fig. 4). At an advanced stage of the erosion of such a "step up," only isolated individual columns remain, rather like bollards, on the surface of the platforms (Pl. I., fig. 5).

Residuals of the upper flow sometimes remain as rock stacks on the storm-wave platforms (Pl. I., figs. 2, 6). Pyramid Rock, at the midpoint of this western section of the southern coast, is a rock stack of residual basalt columns, surrounded by a "skirt" of scree, on an irregular platform of pinkish granite (Pl. II., figs. 1, 2). The granite platform is separated from the main island by a narrow channel formed along a master joint.

The surfaces of the storm-wave platforms are relatively smooth where they retain a veneer of the red band (Pl. I., fig. 4). Where the red band has been stripped completely from the platform, its surface is usually grooved by a network of gutterways which follow the columnar joints of the basalt. The basalt adjacent to the joints shows apparent pseudo-flow structure parallel to the jointing. This is an effect of directed attrition by sand and similar fine material swept along the gutterways.

Some platforms show sloping surfaces and abrupt changes in level where they are cut in gently dipping basalt flows of different hardness, or where, as at the eastern end of Smith's Beach, they intersect a sloping bed of silicified gravel intercalated with the basalts. Pot holes, containing more or less spherical pebbles, are sometimes present.

Some platforms show a well-defined "rampart" at their seaward edge, but others remain uniformly level right to the edge (Pl. I., figs. 1, 2). The seaward face or "nip" (Edwards, 1941) is steep to vertical, though sometimes bevelled at the top.

The line of cliffs is broken at Summerland's Bay and at Kitty Miller's Bay by stretches of beach, backed by sand dunes up to 50 feet high. These cap the tie bars joining Summerland's Island and Phelan's Island to the main island. At the head of Kitty Miller's Bay, the dunes have buried a boulder beach rising for 15 to 20 feet above high-tide level.

Small bay-head beaches occur in the embayments near Helen's Head, at the mouth of Native Dog Creek (Barry's Beach), and at a few other points. The cliff line is otherwise unbroken as far as Smith's Beach, where there is a long stretch of beach with dunes accumulating on sloping cliffs of weathered basalt overlain by laterised tuffs. East of this point the proportion of beach to cliffs and storm-wave platforms increases, until beyond Forrest Caves the transition to the second section of the coastline is complete.

The second section of the southern coastline extends from Forrest Caves to the beginning of the granite cliffs near Cape Woolamai. It consists of a sandy beach, with occasional outcrops of basalt in the shore platform, and is backed by cliffs cut in sand dunes that rise to 100 feet above sea-level, and form the tie-bar connecting the tied islands to the main island. The dunes are migrating inland. Forrest Caves are two small caves about 10 feet high, cut in the face of a storm-wave platform of laterised tuff. Their roofs have partly collapsed, and they are submerged at high tide.

The third and most rugged section of the coast consists of the granite cliffs in the vicinity of Cape Woolamai. The tilt of the surface of the granitic stock at 5° to the north (Edwards, 1942)

results in an increase of cliff height southwards, until at Cape Woolamai the cliffs are about 250 feet high. The cliffs along the south-western side of the tied island, facing the strongest wave attack (Pl. II., figs. 5, 6) present a bolder and more rugged aspect than those on the south-eastern side (Pl. II., fig. 4). Erosion has driven deeply along the joint planes of the granite, forming gorge-like indentations (Pl. II., fig. 6), sometimes fronted by jagged pyramidal rock stacks, cut off from the cliffs at high tide (Pl. II., fig. 5). Storm-tossed boulders are found along even the highest cliff tops. On the south-eastern side of the tied island the cliffs are very steep, but the headlands are widely spaced between smoothly curved embayments, and the shallow bayheads are backed by a narrow, shelving beach (Pl. II., fig. 4). There are no storm-wave platforms along this section of the coast, presumably because the rocks are too hard to permit any distinctive low-tide erosion (Edwards, 1941).

Proceeding northwards along the Eastern Passage, the height of the cliffs decreases, until a little north of the old granite quarry and its jetty they give place to smoothly rounded sand dunes (Pl. II., fig. 7), which are migrating northwards along the tie-bar, and occasional outcrops of basalt at sea-level. Still further north, the coast is protected from all wave attack, and the high-tide level is marked by a slight nip, with trees and grasses coming down almost to high water level.

THE NORTHERN COASTLINE.

The northern coastline is largely screened from wave attack by French Island and by the easterly extension of the Mornington Peninsula to Sandy Point. These obstacles prevent the development of large waves under the influence of northerly winds, even during gales. The composite tie-bars and islands at the eastern end of Phillip Island effectively shelter the island from south-easterly winds, and prevent rollers from passing through the Eastern Passage. The broad Western Passage, however, faces directly towards the south-west, and affords an easy passage for waves and rollers coming from this direction. Where these waves impinge on the northern coastline in the vicinity of The Knobby and along the north-western side of Summerland's Island, they have cut steep cliffs in the basalt comparable with those along the southern coast. Further from the mouth of Western Passage the strength of the wave action is reduced by the shallow reefs and banks in the Passage, and the land surface becomes lower. A sandy beach begins at Cat Bay (Pl. III., fig. 3), and extends with only minor breaks almost to Rhyll. Beach cusps are often prominent along the section between Cat Bay and McHaffie's Reef. In the sheltered part of Cat Bay, a sand ridge has formed in front of the cliffs, from which it is separated by a shallow swale (Pl. III., fig. 3), and high dunes have formed along the tie-bar joining Summerland's Island to the main island. Cliffs

up to 50 feet high persist from north of Cat Bay jetty to McHaffie's Reef. They are cut chiefly in red tuff or decomposed basalt. The tuff overlies the basalt. Fresh basalt is exposed only below high tide mark at the headlands. Sand has accumulated on top of the cliffs, and is migrating inland. Wind erosion has exposed numerous calcareous concretions and root moulds.

At McHaffie's Reef, vertical cliffs up to 50 feet high occur in sloping beds of red tuff, overlying weathered basalt (Pl. III., fig. 2), and a small storm-wave platform has been cut in the tuff on the northern side of the headland (Pl. III., fig. 1).

North of McHaffie's Reef, the coastline trends about 30° N. of E., so that the south-west waves set obliquely to the shore. Longshore drifting of the sand tends to silt up the creek mouths, and the cliffs, which are reduced to 25 feet in height, are faced by one or two sand ridges along the backshore. Low vertical cliffs recur at Penguin Point, where beds of red tuff come down to sea-level. The northerly dip of these beds causes them to strike across the line of the beach.

Beyond Penguin Point, the coastline trends east. The low sandy cliffs continue behind a widening stretch of sloping sandy beach, with a broad shore platform cut in basalt or tuff showing at low tide. The coast is prograding and the shoreline has advanced about 100 yards from the cliff. According to information received from residents, the advance is about 1 yard a year. The back shore consists of one or more ridges of fixed sand, separated from the old cliff line by a broad swale. The beach slopes steeply between high and low water marks, and at low tide there is a strong issue of seepages a few feet above the low water along almost the whole length of the beach. Three small headlands of red tuff, the Mussel Rocks, break the beach line close to Cowes pier.

East of Cowes pier the waves produced by both south-westerly and north-westerly winds combine to set up long-shore drift to the east, with little or no counter tendency from the shallow and sheltered eastern part of Western Port Bay. The eastward drift has caused the formation of a spit, which is now $3\frac{1}{2}$ miles long and is still building out eastwards (Pl. III., fig. 4). This spit has grown across the mouth of a large bay, silted up into a salt marsh, part of which has been drained (Pl. III., fig. 7). The original coastline is marked by a line of cliffs continuous with the present cliffs facing the Nits near Rhyll, and extending almost to Cowes. The older part of the spit is covered by dunes which carry thick tea-tree scrub, but the eastern end is a bare sand bar (Pl. III., fig. 4). The tip of the spit is exposed only at low tide, for a distance of about 1,000 yards, and is becoming compound. The part of the bay still open behind the spit is largely mangrove swamp.

Prior to the growth of the spit, steep cliffs 50 feet high were cut in Jurassic sediments and Tertiary basalts that outcrop west of Rhyll (Pl. III., fig. 5). Where protected by the spit, these cliffs are weathering to form gentle slopes, but at the north-east corner of the island, where the coastline turns southwards, they are exposed to wave attack and are nearly vertical. The basalt of which they are composed is largely decomposed above high water mark.

South of Fisherman's Point at Rhyll, where the coast is protected from all but occasional small waves, progradation is taking place, and a sandy flat extends out some hundreds of yards from the old cliff line which is now rounded and grassed, to a "nip" about 4 feet high, fronted by a beach a few yards wide (Pl. III., fig. 8). Bores at intervals up to 175 feet out to sea from the jetty show that the original surface of the sea floor has been buried beneath more than 50 feet of muds. The head of the bay between Fisherman's Point and Long Point is partly silted up, and the silting up process extends around Long Point into Swan Corner (Pl. III., fig. 6), which is sheltered by Churchill Island. At low tide, Swan Corner becomes a mud flat with a shallow channel in the centre, but an old cliff line is evidence of past wave attacks. At Newhaven, beyond the shelter of Churchill Island, cliffs develop again, in decomposed basalt, and similar cliffs occur on the north-eastern side of Churchill Island.

General Geology.

Phillip Island consists essentially of a number of flows of Tertiary Older Volcanic basalts, intercalated with beds of red tuff and agglomerate, and overlying Jurassic and Palaeozoic sediments and Palaeozoic granites. Outcrops are largely obscured by soil and alluvium, and near the coast by sand dunes.

The earliest description of the geology is given by Blandowski (1857) in a report on his journey from King's Station to Bass River, Phillip and French Islands. The Woolamai granite has been described by McNerny (1929), but apart from this other geologists have made only passing reference to the island. The south-eastern corner of Phillip Island was mapped by Stirling in 1892, as part of Quarter Sheet 76 SW., and during the present work an incomplete manuscript map of the island by Stanley Hunter was made available to the author by the courtesy of Mr. W. Baragwanath, Director of the Geological Survey of Victoria.

PALAEOZOIC SEDIMENTS.

Although not outcropping on Phillip Island, Palaeozoic sediments have been proved in situ in deep bores at Cowes (Bore No. 2) at a depth of 306 feet below sea-level, and at Rhyll (Bore No. 1) at a depth of 459 feet. Sandstones presumably of

Palaeozoic age were encountered at a depth of 216 feet in Bore No. 8, in allotment 143. Xenoliths of little altered rock, several feet across occur in the granite outcrop opposite Pyramid Rock.

The Palaeozoic sediments must occur in the sea-bed in the vicinity of Cape Woolamai, because boulders of hornfels and indurated sandstone are found on the southern beaches in the vicinity of the granite stock, and similar boulders are found along the south-western cliffs of the granite area, where they have been tossed up by storm waves. It seems likely that these rocks form the sea-bed over a considerable area between Cape Woolamai and Pyramid Rock.

The sediments are probably of Ordovician age, since Ordovician graptolites have been found in boulders of slate near Griffith's Point, on the San Remo Peninsula (Hall, 1904).

JURASSIC SEDIMENTS.

As noted by Blandowski (1857), Jurassic strata outcrop in the north-eastern corner of the island, in the cliff section facing the Nits, west of Rhyll township (fig. 1). They extend inland for about $\frac{1}{4}$ mile, and then pass beneath alluvium and Tertiary basalts. The cliff section is about 50 feet high, and excellent exposures are afforded in quarries along the cliff face (Pl. III., fig. 5). The sediments consist of felspathic grits and friable arkose, with a few thin beds of grey and black mudstones. The mudstones contain fragmentary plant remains such as *Alcithopteris* sp., and *Sphenopteris* sp., sufficient to establish their Jurassic age.

The beds dip southwards, and show gentle fold undulations along the cliff face. Blandowski concluded that these beds underlie the inlet to the north, and estimated their thickness at between 400 and 500 feet. This is borne out by Bore No. 1 in allotment 17, which passed from Jurassic to Palaeozoic strata at a depth of 459 feet below sea-level (Ann. Rept. Dept. Mines, for 1912, p. 137). No other outcrop of Jurassic rocks is known on the island, but the Cowes bore put down at sea-level in the Recreation Reserve, encountered a thickness of 120 feet of Jurassic strata beneath 186 feet of basalts and tuffs. Bore No. 7 at Newhaven reached the Jurassic at a depth of 294 feet in allotment 13 (fig. 1).

TERTIARY SEDIMENTS.

Thin beds of pre-basaltic gravels, derived from the adjacent granite, occur in the cliffs facing Pyramid Rock, and along the northern margin of the Cape Woolamai granite. Post-basaltic gravels of a similar character cap the basalt flow facing Pyramid Rock, and an inter-basaltic gravel, about 10 feet thick, which has been converted to quartzite, is found at the eastern end of Smith's Beach, where it outcrops as a ridge in the storm-wave platform. Boulders of this quartzite are numerous along the adjacent

beaches. The outcrop is crescentic to the south, and dips inwards, indicating that it was deposited in a north-sloping valley in the underlying basalt.

Red gravels, up to 10 feet thick, overlying decomposed basalt, outcrop from beneath the dunes just north of Cat Bay jetty. They resemble the "Red Beds" above Older Volcanic basalts at Stony Point and at Corinella Point, on the western and eastern shores of Western Port.

RECENT SEDIMENTS.

Alluvium fills most of the shallow valleys on the island, and dune sands are found at intervals along the coast, especially along the tie-bars. Recent sands and gravels are developed where the sheltered portions of the coast are prograding.

IGNEOUS ROCKS.

AMPHIBOLITES.

Numerous boulders of amphibolite have been washed up in the shingle and boulder beach along the western side of Kitty Miller's Bay (Phelan's Bluff). They may be derived from Pre-Cambrian rocks offshore, but it seems more probable that they are derived from the ballast of the "Speke," which was wrecked off this point in February, 1906.

GRANITES.

Granites, presumably of Devonian age, outcrop in the south-eastern extremity of the island, at Cape Woolamai, and at Pyramid Rock, midway along the southern coast (fig. 1).

The Woolamai granite is a stock-like body, covering an area of about 4 square miles. The eroded surface of the stock slopes at 5° N. The stock was originally part of the Bass horst, and owes its northward tilt to the fault movements that gave rise to the horst (Edwards, 1942). Good exposures are limited to the cliffs. The rock has been described by McInerny (1929), and its heavy minerals have been listed by Baker (1942). It is the most acid of analysed Victorian granites. It consists of quartz, microperthite and oligoclase, and occasional flakes of biotite. Some of the biotite is altered to chlorite, which accounts for "the intense green colour of the mica" noted by Blandowski (1857, p. 54). The microperthite contains much iron oxide dust, which causes it to appear a pleasing pink in the hand specimen. The rock is relatively coarse-grained, individual crystals averaging about 3 mm. across. It has a high crushing strength (27,100 lb. per sq. in.).

The granite has been quarried for building purposes on the eastern side of the stock, close to water level. It is strongly jointed; in the vicinity of the quarry, one set of master joints strikes N.-S., and dips at 60° E., another strikes E.-W., and dips.

at 30°S. On the opposite side of the island, this jointing has given rise to pyramidal rock stacks. Along the south-eastern part of the coast, two sets of flat dipping joints, one dipping east and the other west, combine with nearly vertical joints to produce a columnar or "blocky" structure in the cliffs.

Veins and segregations of aplite and pegmatite traverse the granite in places. Crystals of reddish-brown orthoclase an inch or more long are found in vughs in the pegmatites. Xenoliths and segregations of basic minerals are generally absent.

At its northern end, the granite is overlain by thin beds of Tertiary gravels, largely derived from the granite, and by Tertiary basalts, and Recent dunes.

Granite outcrops at the base of Pyramid rock in the cliffs of the main island, where it is overlain by thin grit beds, and by columnar basalt. This outcrop is finer-grained than the Woolamai granite, but is otherwise similar. It contains xenoliths of Palaeozoic sediments ranging up to 3 feet across. The larger xenoliths are practically undigested.

TERTIARY VOLCANIC ROCKS.

The Tertiary volcanic rocks consist of flows of basalt of thicknesses ranging from 15 ft. to 90 ft., intercalated with beds of tuff and agglomerate up to 150 feet thick. The tuffaceous material is generally altered to red clay, red ochre, or laterite. The relation of the volcanic rocks to the fault movements that have affected Western Port leaves no doubt that they belong to the Tertiary Older Volcanics, and this is confirmed by the petrological character of the basalts.

PYROCLASTIC ROCKS.

The volume of pyroclastic rocks on Phillip Island appears to equal the volume of lava flows. They are best exposed along the southern coast, between Phelan's Bluff and Forrest Caves. They form prominent red headlands. They show rude stratification, and at Redcliff Head, Smith's Beach, and Forrest Caves, they dip inland at about 5°N. The coarsest agglomerate contains angular fragments of decomposed shaly material several inches across, embedded in red clay. Massive agglomerates grade with decrease in the size of the fragments into beds of ochreous red clay, such as have been found intercalated between the Older Volcanic basalts at Flinders and Korkuperrinnul Creek (Jacobson and Scott, 1937). In places, as east of Forrest Caves, the tuff is only partly ironstained, and unstained grey clays are found with hardened red clay in the joints and bedding planes. The soft grey clay contains about 40 per cent. of gibbsite and halloysite, soluble in sulphuric acid. Where this parti-coloured tuff is subject to wave attack, the grey clay is washed away, leaving a coarsely honeycombed cliff face.

At Smith's Beach, red tuff overlying deeply weathered basalt is completely lateritized.

Ochreous red tuff beds outcrop in the vicinity of McHaffie's Reef and at Penguin Rocks. At McHaffie's Reef, and for about 300 yards south of this headland, the tuffs form a gently domed structure which is exposed in section in the cliffs. Presumably these arched tuff beds are part of an old volcanic cone. Some of the tuff is closely spotted with areas of a white clay-like zeolitic substance, apparently halloysite.

At Penguin Rocks, red tuff beds occur which dip to the north, and form an abrupt low cliff crossing the beach almost at right angles. A quarter of a mile to the south-west what are apparently the same beds outcrop in the beach with a southerly dip. Between these two points the red beds can be observed in the cliff section, where they dip eastwards. Presumably these tuffs mark another centre of eruption.

Similar, but lateritized, red beds form the Mussel Rocks near Cowes Jetty and outcrop in the main street; shallow cuttings along the various roads across the island indicate that the tuffs are widespread. In most of the outcrops they can be seen to overlie basalt flows, but at Smith's Beach a basalt flow can be seen in section, filling a valley eroded in the tuffs.

LAVA FLOWS.

Flows of basalt extend over the greater part of the island, but with a few exceptions, such as Quoin Hill, exposures in the interior of the island are poor. The best exposures are along the southern coast between the Knobby and Summerland's Beach, and between Kitty Miller's Bay and Smith's Beach. Along these sections of the coast as many as five successive flows are exposed in section. The individual flows are from 15 to 90 feet thick.

At Pyramid Rock and at the northern end of the Woolamai granite mass, the basalts can be seen overlying the granite bed-rock, but the bore records show that the base of the basalt series lies well below sea-level—near Newhaven it is between 200 and 290 feet below sea-level, while at Cowes it is about 180 feet below. It is probable, therefore, that the granitic outcrops, and the Jurassic outcrop west of Rhyll, represent hills rising above the general level of the pre-basaltic terrain.

The outcropping basalts are all closely similar. They are under-saturated olivine-basalts, chiefly of the Flinders type (Edwards, 1938). Samples from the two flows encountered in the Cowes bore are also of this type. The rock composing Quoin Hill is an olivine-basalt with titaniferous augite, and is of the Moorooduc type. Thin sections in the Geology Department collection include an olivine basalt of the Keilor type. The only other variant encountered is an olivine-basanite, from the bottom of the gorge

near the mouth of Native Dog Creek. This rock is very closely allied to the characteristic monchiquites of the Older Volcanic series, except for an unusual richness in analcite.

Zeolites, chiefly gmelinite and chabazite, and sometimes aragonite, abound in the vesicles of some of the flows, particularly near their bases, especially in the vicinity of Smith's Bluff and Sutherland's Bluff.

The only prominent point of eruption is Quoin Hill, an almost conical plug which rises steeply to about 150 feet above the surrounding country. A flow appears to have issued from this centre on its west side.

The only chemical analysis of these basalts is that quoted by Skeats (1909) from Selwyn's Catalogue of Rock Specimens and Minerals in the National Museum, Melbourne, 1868. The analysis, which is a second-grade one, shows a general resemblance to analyses of the Flinders type of basalt but is not typical in that the MgO content of the analysed specimen is unusually high, and the CaO content is lower compared with most Victorian analyses.

DYKES.

Several light-coloured dykes of a mugearitic character have been intruded into the basalts in the storm-wave platform at Point Grant. They are up to 2 feet wide, and fill master joints in the basalt, sometimes projecting as low walls. They sometimes step sideways along joint planes, and then resume their main trend, until they split into several branches a few inches wide, each following a separate joint plane. Some movement has taken place since their intrusion, because one dyke was observed to be slightly faulted. The dykes have chilled margins, with a somewhat coarser central part, showing flow banding. They consist essentially of parallel laths of felspar, too altered for precise determination. Much of it appears to be oligoclase. Ferromagnesian minerals, if originally present, were restricted to the groundmass, but the rock is too altered to reveal them.

Several similar dykes intrude the basalts in the shore platforms between Cat Bay jetty and McHaffie's Reef.

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Description of Plates.

PLATE I.

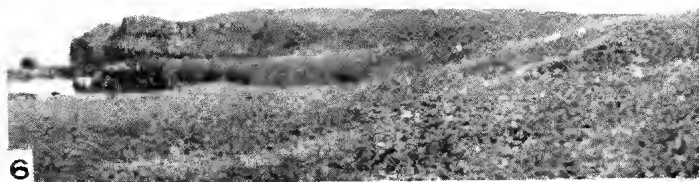
- FIG. 1.—The Knobbly from Summerland's Island, at low tide. Seal Rocks in the distance.
- FIG. 2.—Storm-wave platform with rock stack, cut in horizontal basalt flows, south coast, Summerland's Island, near the blow-hole.
- FIG. 3.—Showing the columnar structure of the basalt overlying the "red band" in which the storm-wave platform is cut.
- FIG. 4.—Surface of a storm-wave platform cut in a "red band", with a "step up" in the left middle distance.
- FIG. 5.—Residual column of basalt with a pedestal of "red band" on a storm-wave platform.
- FIG. 6.—Amphitheatre-like depression in cliff-top, Summerland's Island.

PLATE II.

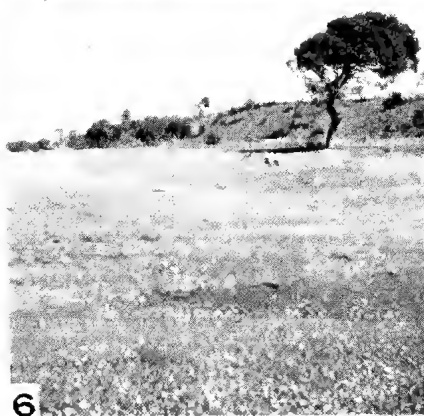
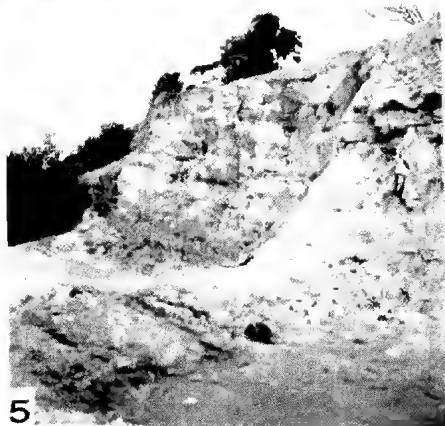
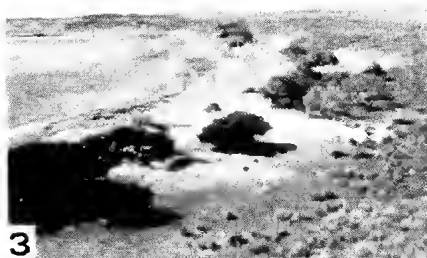
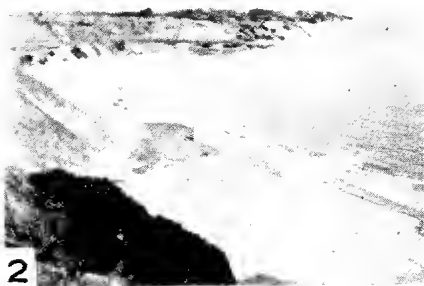
- FIG. 1. Basalt cliffs fronted by storm-wave platform, in the vicinity of Pyramid Rock, near high tide. Cape Woolamai on the skyline.
- FIG. 2.—Pyramid Rock, consisting of a residual of columnar basalt, surrounded by basaltic scree, on a base of lighter-coloured granite.
- FIG. 3. Phelan's Bluff from Kitty Miller's Bay at high tide. The Bluff consists of thick tuff beds overlying a basalt flow which rises to 14 feet above high-tide level. Storm waves have cut back the overlying tuff, giving rise to a high level storm-wave platform, suggestive of recent emergence.
- FIG. 4.—Granite coast on the relatively protected south-eastern side of Cape Woolamai.
- FIG. 5.—Granite coast on the exposed south-western side of Cape Woolamai, showing influence of joint planes on the development of rock stacks.
- FIG. 6.—Granite coast on the exposed south-western side of Cape Woolamai, showing the influence of the joint planes on the development of gorge-like embayments.
- FIG. 7. Sand dunes growing on the protected coast of the Eastern Passage.

PLATE III.

- FIG. 1.—Small storm-wave platform cut in red-tuff at McHaffie's Reef.
- FIG. 2.—Cliff section through domed tuff beds, at McHaffie's Reef.
- FIG. 3.—Dune ridge on the back shore at Cat Bay. Tree-covered dunes fronting Summerland's Island tie-bar in the middle distance, and Quoin Hill on the skyline.
- FIG. 4. End of the spit, fronting Mangrove Swamp, west of Rhyll. French Island on the skyline.
- FIG. 5.—Quarry in Jurassic rocks in the old cliffs north-west of Rhyll.
- FIG. 6.—Prograded beach on Swan Corner.
- FIG. 7.—Silted-up bay behind the spit extending east from Cowes, looking from the top of the old cliff line. The old cliffs can be seen in the distance.
- FIG. 8.—Nip cut in prograded land at Rhyll township.







[PROC. ROY. SOC. VICTORIA, 57 (N.S.), Pts. I-II., 1945.]

ART. II.—*The Stratigraphical Range and Habitat of the
Diprotodontidae in Southern Australia.*

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[Palaeontologist to the National Museum, Melbourne.]

[Read 13th July, 1944; issued separately 10th December, 1945.]

Abstract.

Records of *Diprotodon* and *Nototherium* in Victoria, in the adjoining part of South Australia, and in King Island have been examined and in most cases more or less indefinite localities have been fixed with some precision. The beds containing the *Diprotodontidae* have also, in many cases, been identified.

Owen's locality "near Mount Macedon" for some of his paratypes of *D. australis* is recognized as a spring deposit at Lancefield.

Each occurrence is discussed from the standpoint of its stratigraphy and correlated with the terraces of the Maribyrnong valley, or, where possible, with the scoria cone flows of western Victoria.

The *Diprotodontidae* are believed to be restricted to the Upper Pleistocene or the upper part of the Middle Pleistocene; their appearance is subsequent to the first vulcanism responsible for the Newer Basalt. No remains have been found in beds below the Newer Basalt lava plain phase.

Their habitat is discussed and it is submitted that they flourished when the climate was wetter and the flora more luxuriant, probably during periods when the Upper Pleistocene glaciations occurred in southern latitudes.

Diprotodon is recorded for the first time from King Island, and, as it is a continental genus, it is inferred that the land bridge connecting King Island with the mainland was broken after it first appeared in Victoria, i.e., in the Upper Pleistocene or the late Middle Pleistocene.

The validity of *D. longiceps* as a species is confirmed by a re-examination of McCoy's holotype.

Introduction.

There are records of *Diprotodon* and *Nototherium* from a number of places in southern Australia; this contribution deals with those in Victoria, in the adjoining part of South Australia, and in King Island. Most of the specimens were obtained before 1900 and there is a general lack of detail as to the exact positions and their containing strata. An exception is the North Melbourne specimen recorded by G. B. Pritchard (13); he published a plan on which he accurately marked the position, and in his contribution gave particulars of the stratum. On the other hand, an exhaustive search for additional particulars regarding the important Colac specimen—McCoy's (10) holotype of *Diprotodon longiceps*—has been futile and further information seems to be

now unobtainable. By examining records, some of them made 100 years ago, more or less relevant additional information was obtained regarding many of the specimens. *Diprotodontidae* from the following localities have been dealt with:—

1. North Melbourne.
2. Footscray.
3. Duck Ponds.
4. Limeburner's Point.
5. Lancefield (Mount Macedon).
6. Talbot (Back Creek).
7. Lake Colongulac (Lake Timboon).
8. Colac.
9. Omeo.
10. Buninyong.
11. Coimadai.
12. Watch Hill (? "Murchill").
13. Melton.

The occurrence of *Diprotodon* at Portland and the Goulburn River is mentioned in correspondence but no other particulars are given. Information regarding the molar of *D. australis* (No. 14403) obtained on King Island, and which is here recorded for the first time and discussed from the standpoint of the range of *Diprotodon*, has been supplied by the finder Mr. J. Graham Haines of King Island.

The stratigraphical range of *Diprotodon* and *Nototherium* is correlated here where possible with the succession of fluviatile terraces in the valley of the Maribyrnong River worked out by R. A. Keble and J. Hope Macpherson, more detailed particulars of which are to be published shortly in the Memoirs of the National Museum, Melbourne. Some occurrences are correlated with the succession of lava flows and tuffs implied by H. J. Grayson and D. J. Mahony's Memoir (5) on the Camperdown and Mount Elephant districts. *Nototherium* has been found in the same bed as *Diprotodon* at Talbot (Back Creek), Lancefield (Mount Macedon), and Omeo. At Buninyong, Coimadai, Watch Hill (?), and the bed of a creek about 1 mile north-east of Melton it occurs without *Diprotodon*.

The *Diprotodon* and *Nototherium* remains at North Melbourne, Footscray, Duck Ponds, Limeburner's Point, and Coimadai were found in fluviatile or lacustrine beds deposited in tributary valleys of the Yarra stream system. The bathymetrical contours of Port Phillip Bay—a sunkland on which the lower reaches of the Yarra stream system have been submerged—disclose delta deposits and wave platforms that may be correlated with the Maribyrnong Valley fluviatile cycles. There are no Pleistocene glacial deposits in Victoria, but Keble and Macpherson have assumed that the terraces, platforms, etc., were formed by eustatic adjustments of

sea level caused by glaciations in other regions. They found that the Maribyrnong Valley was little affected by tectonic movements, which usually took the form of warping and tilting. Their succession, with a correlation with the European glacial and interglacial stages indicated by F. E. Zeuner (21), is as follows:—

Age.	European Stages.	Maribyrnong River Cycles.	Maribyrnong River Phases.
Recent	{ Post	Present Cycle	{ Recent
	{ Glacial		{ Maribyrnong Terrace
	{ W3	Maribyrnong Cycle	{ Maribyrnong Flood Plain
Upper Pleistocene	{ W2/W3		{ Braybrook Terrace
	{ W2	Braybrook Cycle	{ Braybrook Flood Plain
	{ W1/W2		{ Keilor Terrace
	{ W1	Keilor Cycle	{ Keilor Flood Plain
	{ Pre-Wurm		{ Vertical erosion
Middle-Lower Pleistocene	{ NEWER BASALT (lava plain phase)		

The duration of the vertical erosion that preceded the deposition of the Keilor Flood Plain is uncertain; a Middle-Lower Pleistocene age is assumed for the lava plain phase Newer Basalt on which the vertical erosion was initiated. There is, however, an unbroken sequence back from the Recent to the Keilor Flood Plain.

Grayson and Mahony (5) divide the basalts of Camperdown and Mount Elephant into two groups, which, they say, differ in relative age and to a certain extent in character. They use the terms "earlier" and "later" for these basalts.

The origin of the "earlier" basalts (the Newer Basalt in Keble and Macpherson's succession) which are exposed over very considerable areas and up to 100 feet thick is, they state, very obscure. They state also that the lava plains—the surface of these earlier basalts—are traversed by natural drainage channels and there are on them depressions with gently sloping sides, in which water lies for long periods. But it should be pointed out that there is evidence of an earlier drainage system—old flood plains that do not now function—in the districts. No remains of the *Diprotodontidae* have been found under the "earlier" basalts.

The Hampden Tuffs, the name given to the tuffs of the districts, which cover a considerable area around Camperdown and Lake Keilambete and on the floor of Lake Bookar at Terang, are bedded and distinct from the heaps of scoria around the scoria cones from which the "later" basalts came; they were stratified while the volcano from which they came was in active operation. They may be regarded as a series intermediate between the "earlier" and "later" basalts: the "later" flows at places rest on them. Besides covering the beds of lakes within the area over which they fell, they probably also covered the drainage

channels and depressions on the "earlier" flows and those of the older drainage system that preceded it. Under the Hampden Tuffs, where drainage channels and depressions existed, alluvial and lacustrine deposits probably occur and it is possible that some of the remains of *Diprotodontidae* in bone beds on the shores of lakes may have been derived from some of these resorted older deposits, as, for instance, those of Lake Colongulac.

The "later" basalts are always closely associated with the scoria cones—the points from which they were erupted. The flows are often slightly raised above the general surface of the "earlier" lava plain and form low platforms from which the scoria cones rise. In many cases the flows are of limited extent and at Mount Terang there is a good section in which four distinct flows together forming a thickness of 15 feet and associated with unstratified scoria are exposed and rest on the undenuded surface of the bedded tuffs—the Hampden Tuffs. Grayson and Mahony regard the "later" basalts as of very recent origin and that though they are "approximately of the same age, some of these flows are no doubt considerably older than others, and no sharp line can be drawn between them and the earlier basalts."

The *Diprotodontidae* that were obtained at Talbot probably came from a lacustrine deposit formed in a lake due to the damming of Back Creek by a scoria cone flow across its outlet; the sub-basalt lake at Buninyong was likewise formed by damming, in this case by the Yarrowee flow. The Mount Gambier and Mount Schanck remains were found under volcanic ash that came from those recent craters.

Grayson and Mahony's recognition of "earlier" and "later" basalts and the intermediate Hampden Tuffs in the Camperdown and Mount Elephant districts is taken here to apply generally to the volcanic activity throughout Victoria known as the Newer Basalt. In interpreting the geological maps it has been found convenient to refer to the "earlier" basalts as the lava plain phase and the "later" basalts as scoria cone phase.

Up to the present it has not been found possible to correlate the cycles of erosion and fluvial deposits of the Maribyrnong Valley with the Hampden Tuffs and the scoria cone flows; the only correlative datum is that both series post-date the lava plain phase. But every horizon in the bedded Hampden Tuffs, each scoria cone flow, and each fluvial and lacustrine deposit in the Western District is contemporaneous with some part of the Maribyrnong Valley fluvial deposits or river cycles. It is noteworthy, however, that although there are scoria cones in the Maribyrnong Valley, at no place is a scoria cone flow found resting on a river terrace or is volcanic ejectamenta bedded with the fluvial deposits. On the other hand, there is evidence in

the Duck Ponds Valley of a lava flow, presumably from a nearby scoria cone, having flowed on to the Keilor Flood Plain, damming the stream to form the lake in which the freshwater limestones, the beds containing *D. longiceps* accumulated. The Burnley basalt also covered fluviatile deposits in the valley of the Yarra that extend into and cover the *Diprotodon* beds of North Melbourne and Footscray.

Occurrences of the *Diprotodontidae*.

1.—NORTH MELBOURNE.

In 1899 a fairly large fragment of the right half of the lower jaw of *D. australis* Owen was found in the excavations for the main sewer at Arden-street, North Melbourne. G. B. Pritchard (13) states: "the present example was found in a tunnel excavation under the Moonee Ponds Creek near Arden-street, North Melbourne, the depth of the tunnel below the present bed of the creek being approximately 25 or 35 feet below the surface . . . The matrix in which the bone was found is a sandy clay of a fawn or brownish colour, containing glassy quartz grains up to one-sixteenth of an inch in diameter—some well rounded, while others are sub-angular—and small flakes of white mica, apparently muscovite . . . In the extension of this same sewer towards Kensington at a distance of about 200 feet from where the bone was found, numbers of marine shells were found, all of which appear to be recent species, and this close association of these remains seems to warrant the application of Pleistocene for the geological age of the deposits in the area."

The log of the bore put down where the *Diprotodon* was found by the Melbourne and Metropolitan Board of Works was—

a. Filling	..	..	..	10 feet.
b. Silt	..	..	..	19 feet.
c. Yellow and red clay	..	..	..	8 feet.
d. Sandy clay	..	..	..	17 feet.
Total depth ..				54 feet.

The specimen came from bed "d."

The sequence of the fluviatile deposits and cycles of the Moonee Ponds Creek, and incidentally, the Maribyrnong and Yarra Rivers was as follows:—

Raised Beach ?.

Flood plain deposited in diverted stream (Yarra River).

Dune encroachment. Diversion of Moonee Ponds Creek and captured Yarra into the Maribyrnong River.

Capture of the Yarra by Moonee Ponds Creek after the Burnley Basalt (scoria cone phase).

Flood plain deposits—beds "b" and "c" in above log.

Vertical erosion.

Sandy clay, etc—*Diprotodon* bed, "d" in above log.

As regards the age of the *Diprotodon* bed it is either at the base of the Recent or the summit of the Pleistocene.

2.—FOOTSCRAY.

In January, 1899, *D. australis* was found in Footscray. The specimen (No. 13,000) represents most of the left ramus of the lower jaw with its fore part and symphyseal boss: in their sockets are three worn molars (M1, 2 & 3), two imperfect pre-molars (D3 & 4), and the socketed portions of two broken-off incisors. It was found at a depth of 36 feet in sewerage excavations. These are all the facts that have been recorded concerning the specimen, but old records kept by the Melbourne and Metropolitan Board of Works enable its locality to be fixed within narrow limits.

The depth from which it was obtained indicates that it came from excavations for a main sewer. In 1899 and previous to that year, in Footscray proper, only the excavations for the main sewer between the Maribyrnong River and Lloyd-street reached a depth of 36 feet. The area on the left bank for some distance to the east was then part of Footscray and the excavations in this part were also 36 feet deep but gradually shallowing to the east. The bores put down by the Board on the right bank were in the lava plain phase of Newer Basalt except Bore No. 43 which was on the toe of the bank 200 feet downstream from the Napier-street Bridge. The log of this bore was—

a. Filling	..	..	..	..	4 feet.
b. Silt	..	..	..	..	5 feet.
c. Clay	..	..	..	..	35 feet.
d. Sand	..	..	..	..	2 feet.
Total depth					46 feet.

A section across the Maribyrnong River available from the logs of bores put down by the Railway Department along the Footscray to Melbourne railway line about $\frac{3}{4}$ mile to the north of the sewer shows a few feet of sand resting on river silt and mud, which occupies a river channel cut in sandy clay. The matrix adherent to and in the crevices of the jaw bone is a clay containing coarse quartz sand and there is little doubt that the *Diprotodon* came from bed "c" in the log of Bore No. 43.

The Footscray sewer is the westerly extension of that at North Melbourne in excavating which Pritchard's *Diprotodon* was found, and the containing bed at Footscray is probably a westerly extension of the North Melbourne bed.

3 AND 4.—DUCK PONDS AND LIMEBURNER'S POINT.

R. Daintree (4) states in his report on Quarter Sheets 19 S.E., 24 N.E., and 24 S.E.: "The deposits of freshwater limestone at Limeburner's Point, Geelong, and the Duck Ponds, appear to have taken place just after the close of the volcanic period, and before the subsidence of the land to receive the sea which deposited the Queenscliff beds."

Diprotodon has been found at both places, and judging by the similarities in the fossil freshwater shelly fauna and the lithology of each deposit they were deposited under the same conditions and were contemporaneous. The geological history of Duck Ponds, sometimes referred to as Duck Ponds Creek or Hovell's Creek, is clearer than that of Limeburner's Point and is dealt with here at some length.

3.—DUCK PONDS.

The exact locality and the bed from which the upper and lower incisors (No. 1892-3) identified by McCoy (10) as belonging to *Diprotodon longiceps* were obtained by the Rev. C. S. Y. Price, has not been recorded. The specimens are so well-preserved—there is little mineral replacement and an absence of adherent matrix—that a doubt arises as to whether they were *in situ*. A note on Quarter Sheet 24 N.E., viz., "Lime kilns in excavating which several bone caves were found," increases this doubt. In the absence of information to the contrary, however, and the fact that the Limeburner's Point specimen was definitely *in situ* in what appears to be the same bed, it has been assumed that the Duck Ponds specimens were obtained from the limestone.

Daintree in Quarter Sheets 19 S.E. and 24 N.E. shows the Duck Ponds freshwater limestone as occupying the valley of Duck Ponds Creek. The succession shown by him on those Quarter Sheets may be tabulated as follows:—

A	Alluvial, fluvial and swamp deposits	..	Recent
Pl	a. Estuary beds; b. Raised beaches	..	Post Pliocene
TPN	Calcareous clay, sandy beds, gravel	..	Newer Pliocene
L	Freshwater limestone	..	Tertiary
V	Upper Volcanic [lava plain phase]		Pliocene
TP	Sandy beds, clay, shale	..	Older Pliocene
TM	Marine limestones, clays, &c.	..	Miocene

The following is an interpretation of the succession in terms of sedimentation and stream development derived from surface physiographical evidence: the lava plain phase of the Newer Basalt obliterated all earlier physiographical features. The symbols used on the Quarter Sheets in the foregoing summary of Daintree's succession are given to facilitate comparison with it and the cycles and terraces worked out by Kelble and

Macpherson in the Maribyrnong River Valley. It will be noted that the Upper Volcanic (V) or Newer Basalt lava plain phase is regarded as Lower-Middle Pleistocene, not Pliocene, the age assigned to it by Daintree.

1. A	Alluvial, fluviatile and swamp deposits ..	}	Recent
2. Pl	Estuary beds, raised beaches		
3.	Rejuvenation		
4.	Low level flood plain deposits in tributaries	}	Maribyrnong Cycle
5.	Rejuvenation. Breach of dam		
6.	High level flood plain deposits in tributaries following 7	}	? Braybrook Cycle
7.	Vertical erosion		
8.	Regional subsidence on Lovely Banks Monocline	}	Keilor Cycle
9. TPN	Calcareous clay, sandy beds, gravel, &c. ..		
10. L	Deposition of <i>Diprotodon</i> fresh water limestone		
11.	? scoria cone flow dams Duck Ponds valley ..		
12.	Flood plain deposits in railway bores following 13.		
13.	Vertical erosion of Duck Ponds Creek ..		
14. V	Upper Volcanic (lava plain phase)		

Sections of the freshwater limestone (L) disclosed by wells and bores put down by the Railway Department show that it rests on flood plain deposits. A well sunk at its northern extremity gave the following section, particularized on Quarter Sheet 19 S.E.:—

TPN	Soft sandy loam	4 feet
L	Rubbly limestone	6 feet
	Compact limestone, containing fresh water shells Planorbis, Limnaea	4 feet
	Soft rubbly limestone	6 feet
	Calcareous sandy clay	4 feet
V	Soft decomposed basalt	2 feet
Total depth		26 feet

The bores put down for the Railway Department were for the foundations of the bridge to carry the Geelong-Melbourne railway over Duck Ponds Creek. The deepest bores reached a depth of 30 feet below sea level and passed through intercalated muds, clays, sands, and gravels; only one bore encountered limestone—a bed 5 feet thick—5 feet above sea level. The significant information supplied by the bores is that 21 feet under the bed of Duck Ponds Creek a bed of “quartz gravel and rotten shells” overlies stiff clay; unfortunately we are not told whether the

"rotten shells" were freshwater or marine. The horizon of the single bed of limestone is 14 feet above the shelly quartz gravel. The bores penetrated other shelly beds, lateral extensions of the tidal deposits at present tide limit in the bed of the Creek. On Quarter Sheet 24 N.E. there is a reference to a "cliff section showing about 20 feet yellow sandy limestone"; this limestone is at a higher horizon than any of the beds disclosed by the railway bores. The combined deposit shown on the Quarter Sheets as freshwater limestone (L) is about 70 feet thick, 40 feet of which are mostly freshwater limestone and 30 feet almost exclusively flood plain non-calcareous deposits. The bores passed through, for the most part, flood plain deposits of the stream formed during the first cycle of erosion after the Newer Volcanic, i.e., the Keilor cycle. This flood plain is correlated with the Keilor flood plain of the Maribyrnong Valley—the first flood plain formed in that valley. The freshwater limestones of Duck Ponds Creek are newer—the upward lacustrine extension of the flood plain deposits—but there was little, if any, time break between the two deposits.

The flood plain deposits of the Braybrook cycle are probably represented in the gully artificially dammed to form a lake north of Lara and also in the gully similarly dammed to form Lara Lake. The flood plain deposits in the lower reaches of this Lara Lake gully have been correlated with the Maribyrnong cycle.

Summarizing these remarks, the age of the Duck Ponds incisors of *Diprotodon longiceps* are early Upper Pleistocene and the containing beds a late equivalent of the Keilor Flood Plain in the Maribyrnong River Valley succession.

4.—LIMEBURNER'S POINT.

Limeburner's Point or Galena Point as it is called on Quarter Sheet 24 S.E. and most maps, is on the south side of the Inner Harbour of Corio Bay; it rises rather steeply from the sea to a height of about 70 feet. Quarter Sheet 24 S.E. was surveyed in 1863 by R. Daintree (4), and the following are the particulars of the limestone given by him in his report on the Sheet: "The section afforded in the thickest part of the limestone deposit at Limeburner's Point is—

7 feet	Marly clay	} Marine Shells
10 feet	Ferruginous sandy clay with marine shells	
3 feet 6 inches	Rubbly limestone	} Freshwater shells Planorbis Lymnea, &c.
3 feet 6 inches	Thin-bedded limestone	
7 feet	Very compact limestone, principal bed used for lime	
6 feet	Rubbly thin-bedded ferruginous limestone resting on Miocene tertiary sandy marl.	

This closely agrees with Note 3 printed on the margin of the Sheet.

It will be noted that the freshwater shells are identical with those obtained in the well (p. 30) in the Duck Ponds limestone. *Diprotodon longiceps* was obtained *in situ* in the 7-ft. bed of "very compact limestone." The specimen (No. 13303) identified by McCoy (10) shows a horizontal section of the molars and a vertical section of the incisors.

The freshwater limestone (L) outcrops at and extends some feet above and below sea level, a fact that clearly indicates a relative subsidence of the freshwater beds. The calcareous clay, sandy beds, gravel, etc. (TPN), overlie both the lava plain phase of the Upper Volcanic (V) and the freshwater limestone (L); and in some places the Miocene sediments. The interpretation of the geology of Limeburner's Point is somewhat difficult owing to the area to the north being one of subsidence and submerged by the water of Inner Harbour. There is little doubt, as Daintree asserts, that the limestones of Limeburner's Point and Duck Ponds are of lacustrine origin and contemporaneous; their lithology and fossils are identical. At Limeburner's Point the lacustrine limestone rests on the scarp of the sink that formed the Inner Harbor; it outcrops from 25 to 70 feet below the surface of the upper Volcanic (V) presumably the extension southwards of that in the Duck Ponds Valley on which there the limestone and fluvatile beds rest. The 17 feet of marly and ferruginous sandy clays containing marine shells are probably partly a raised beach.

The succession of events has been—

	Duck Ponds Equivalent.
1. Raised Beach	2
2. Regional subsidence and marine transgression forming Inner Harbour	8
3. Widespread deposition of calcareous clays, sandy beds, gravels, &c., (TPN) on the surface of the freshwater limestone (L), Upper Volcanic (V), and Miocene sediments	9
4. Deposition of the <i>Diprotodon</i> freshwater limestone (L) in the sink and on its scarp	10
5. Tectonic sink during the Keilor Cycle	

5.—LANCEFIELD (MOUNT MACEDON).

In 1844 Richard Owen (12) in a report to the British Association for the Advancement of Science on the extinct mammals of Australia spoke of some fossils received by the Royal College of

Surgeons, London, from Dr. Hobson of Melbourne. The following is an acknowledgment to Hobson by Owen of the receipt of the fossils:—

RI. College of Surgeons,
August 26th, 1844.

My dear Dr. Hobson,

I lose no time in gratefully acknowledging the reception of the interesting series of fossils discovered by Mr. Mayne, which you have been so good as to transmit to me, as also the well-marked cranium of the Native of Western Australia. You will perceive by the accompanying sheets that no time has been lost in describing the fossils. They came just as I had completed the catalogue of that series in our Museum and I stopped the press to include your interesting Australian fossils.

Every specimen, except 1498 and 1502, belong demonstratively to the large Marsupial Pachyderm first indicated in Major Mitchell's "Expeditions," Vol. II., p. 362, pl. 31, f. 1 and 2 under the name of *Diprotodon*, signifying two incisors; a genus which I regarded as having an affinity to the Wombat, and which affinity appears to be demonstrated by the calcaneum from the Condamine River transmitted to me by Sir T. Mitchell about a year ago, together with portions of jaw and teeth of *Diprotodon*.

The molar dentition agrees, like that of *Macropus*, in form with that of *Tapirus* and *Dinotherium*, so that altogether the *Diprotodon* is one of the most interesting forms that has been rescued from the great devourer of all things.

I trust that you may be able, through Mr. Mayne and other energetic collectors, to obtain the materials for a complete restoration.

You will perceive also in the descriptions of Nos. 1505-1509, the evidence of an allied genus.

I never had a fossil bone which excited my interest more than 1509, the astragalus of most assuredly a marsupial as large as a Rhinoceros, yet quite distinct from Kangaroo and most like Wombat.

Depend upon it your alluvial or newer tertiary deposits are the grave of many creatures "which have not been dreamt of in our philosophy."

I shall give a sketch of the facts to the Meeting of the Br. Assn. at York, illustrated by Colonel Mitchell's and Mr. Mayne's fossils together with some (including a true *Mastodon*) brought home by Count Strzlecki or Strelinski, who has returned rich in well observed facts from Australia.

always your most sincerely,

Richard Owen.

Owen used the specimens as paratypes of *Diprotodon australis* to explain the dentition of young forms. In 1877 (12) he states: "In 1845 I described and figured a series of teeth, discovered in sinking a well near Mount Macedon, Port Phillip, Province of Victoria . . ." and quotes a letter (13) from Hobson dated January 1, 1845, the portion relating to this discussion being—

"Amongst the secondary hills which skirt the base of Mount Macedon there is a considerable circular plain, which is most elevated in the centre than at the circumference, and which will be better explained by a diagram.



A. A. Volcanic Hills surrounding the plain.

B. B. The plain.

C. A swamp or bog in which are found the bones at a depth of $4\frac{1}{2}$ feet. After digging through a solid peaty soil for 3 feet you then arrive at a stratum of gravel about 18 inches thick, in which the bones are deposited. This layer of gravel rests upon a bed of firm clay, which is unfossiliferous.

The bog or marsh in which the bones are found is about 4 acres in extent, and appears to contain bones at every point. I opened two pits at 150 yards distance from each other and found bones in both, in the same stratum of gravel."

Owen (12) also mentions that in 1844 he received bones from Patrick Mayne from "freshwater beds, Mount Macedon": Mayne informed him by letter that they were "found about 6 feet below the surface in sinking a well." Owen in his report to the British Association alludes to the fact that bones from the same locality as Hobson's came from, were described by F. A. Greeves in a letter to The Port Phillip Patriot on February 3, 1844. In this letter Greeves states that Mr. Mayne made the discovery "in alluvium" near "Mt. Macedon" and that he (Greeves) believed the bones to be the remains of a gigantic wombat. They were brought to Melbourne by Mayne and were subsequently presented to the Museum of the Melbourne Mechanics' Institute; one limb bone (No. 13005) eventually found its way into the collection of the National Museum.

Hobson (8) published an extract from a letter dated February 21, 1844, headed "On Some Fossil Bones discovered at Mt. Macedon, Port Phillip" in which he states—

"the fossil bones of a number of extinct animals have been discovered by Mr. Mayne, near Mount Macedon . . . in a small marsh about 5 feet beneath the surface, embedded in a layer of dark alluvium, about a foot in thickness, upon which are superimposed a bed of yellow clay, and a rich black soil next the surface. The country in the neighbourhood is volcanic and covered with scoriae and vesicular lava."

Hobson (7) also published a letter dated January, 1845, from himself to Ronald C. Gunn, of Launceston, in which he states—

"The bone locality is a large amphitheatre almost surrounded by conical volcanic hills; the centre of the amphitheatre is on a much higher plain than its periphery, and on the top of the little truncated cone there is a marshy looking place covered by a peaty looking vegetation and the soil itself has much the character of peat for three or four feet below the surface. Under the peat is a bed of gravel, in which the bones are deposited in vast quantities, but from there being immediately beneath the bed of gravel a bed of firm ferruginous clay, the water is unable to escape, and in consequence, at this period of the year, it is a work of great labour to obtain any bones and quite impossible to get them without mutilation, owing to the water pouring in to the part dug so fast as to prevent your seeing what you are about. Notwithstanding all this, and we were there only one day,

I succeeded in getting one incisor of an enormous Rodent fully *twelve inches long* and *one and a quarter inches broad* with three huge molars fully *four times as large as those of a Rhinoceros*; with bones of the gigantic kangaroo and those of some large cursorial bird, probably an Emu. The marsh or bog is of the extent of about four acres, and appears to contain bones at every point."

Hobson (8) published an extract of another letter from him to Gunn dated June, 1845, stating that Owen had identified all the specimens from Port Phillip as *Diprotodon* except two; in addition he had identified *Nothotherium*.

It is to be noted that Hobson clearly states that he obtained his bones from a bed of gravel and that both Hobson and Greeves state that Mayne obtained his bones from a (dark) alluvium; both were stated to come from "near Mount Macedon." In the table of localities of *D. australis* published by Owen (12) in 1877 he states that Hobson's bones came from Quaternary gravels and Mayne's from freshwater beds.

The locality given for the discovery "near Mount Macedon" has been a matter for conjecture since Owen (12) published it; an examination of old records makes it clear that the locality was actually Lancefield.

In the early forties—up to 1848—James P. Mayne held the Lancefield Run; it passed from him to Dunsford, who took up the pre-emptive right immediately east of the town of Lancefield. The site of the town was part of the Run and sometimes referred to as Five Mile Creek. The town was surveyed in 1854 and does not appear on the maps of Victoria published before 1850 by Skene and Ham. In 1855 William Blandowski (2) refers to this central part of Victoria as "the ranges known as Mt. Macedon itself." He observes: "Some distance N.E. from the peak of Alexander's Head is a spot where the discovery of bones of gigantic antediluvian *fossil birds* took place, five or six years ago, in a basaltic cavern. I was much disappointed at my ineffectual endeavours to obtain similar specimens, in consequence of my inability to suppress the springs of water sufficiently to enable me to reach the proper depth." The references to "fossil birds" and "a basaltic cavern" are two of the many misstatements found in Blandowski's descriptions, but there is little doubt that he visited the locality where Mayne and Hobson found their bones. In 1863 Norman Taylor (18) stated: "About 1 mile S.W. of Dunsford's (Map 5 S.E.) are 'The Spring' where in digging a waterhole some years back, Mr. Mayne found some gigantic fossil bones at a depth of from 3 to 4 feet. There is no cavern there as stated by Mr. Blandowski." Taylor's reference to the mythical cavern dispels all doubt about them both having visited the same place; the directions given by each, although from different starting points, would bring them to Mayne's bone bed.

On June 14, 1858, about the time Quarter Sheet 5 S.E. was being surveyed by Taylor, McCoy wrote to Owen:

"we are now trying to find some more of the large mammalian remains by excavating in the swamp near Mount Macedon in which were found the large jaws and teeth and bones of extremities sent home to you by Dr. Hobson"

An inspection of the locality indicated by Taylor enables one to fix the swamp where Mayne and Hobson obtained the bones more than a hundred years ago; it is referred to as the "Bone Bed" near the spring on the accompanying sketch map (fig. 1). The

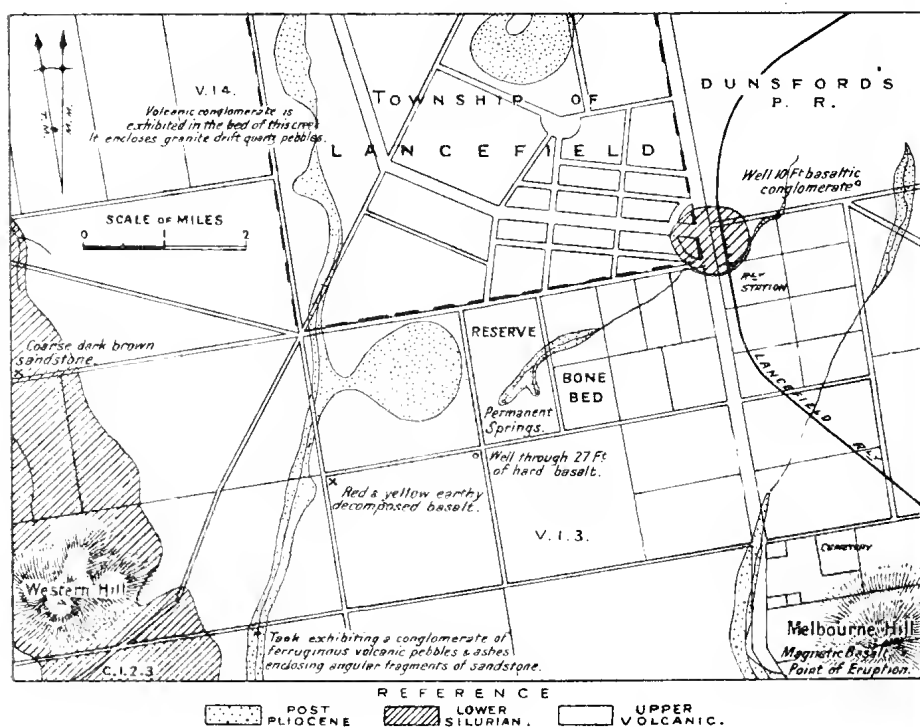


FIG. 1.

eye of the spring has been interfered with and the peaty bed has been turned over by digging at the surface, there is no evidence of gravel having been brought up, but there are pieces of Palaeozoic bedrock lying about suggesting that former excavations may have reached bedrock. If so, the gravels could be

resting on bedrock and be stratigraphically older than the basalt. In the following sections mentioned in Hobson's correspondence, the date of the letter is given:—

21.1.1844 ft. in.	1.1.1845 ft. in.	-.1.1845 ft. in.
Surface	Surface	Surface .. 3 0
Black soil 4 0	Peaty soil .. 3 0	or
Yellow clay	Gravel (bone bed) .. 1 6	Peaty soil .. 4 0
Dark alluvium (bone bed) .. 1 0	Firm clay, unfossiliferous	Gravel (bone bed) ..
		Firm ferruginous clay ..

Bedrock does not appear to have been reached in any of the sections.

The spring apparently owes its existence to sub-basalt or inter-basalt waters finding their way to the surface, but whether through a fracture in the basalt or some part of the basalt has been removed by erosion is not clear. The overflow of the spring has cut a shallow valley trending north-east, obviously the direction of the slope of the lava plain. Near the spring it is cut in peaty beds but further to the north-east is, as shown by Taylor, on the lava plain; it and the peaty soil are newer than the basalt.

As *Diprotodon* and *Nototherium* were attracted to the locality by the spring, which must obviously be later than the lava plain phase of the Newer Basalt; their remains must likewise be later. It is conceivable, however, that the basalt cover from beneath which the spring water comes is a scoria cone flow. This could not be determined without much detailed work, but it may be mentioned that the scoria cone of Melbourne Hill, about 1 mile to the south-east—the nearest scoria cone to the spring—stands on what is assumed to be the lava plain phase of the Newer Basalt.

6.—TALBOT (BACK CREEK).

McCoy (10) with his usual lack of precision in defining localities records *Diprotodon* and *Nototherium* from Back Creek. There are so many Back Creeks in Victoria that its identification would have been impossible but for an amended address in one of his letters, a copy of which is kept at the National Museum, to the finder of the fossils. On October 23, 1861, he wrote to Rob. Wilkinson, chemist, Back Creek:

"Prof. McCoy, as Director of the National Museum of Victoria presents his compliments to Mr. Rob. Wilkinson and begs to say that having examined with great interest the specimen sent to the International Exhibition by him from Back Creek, two of them, viz., one extremity of a long bone and one curved fragment of a tusk would be of the highest interest as additions to the National collection in the Public Museum . . ."

Wilkinson's reply is not filed but McCoy's next letter to him on October 29, 1861, is informative. It is addressed to Rob. Wood Wilkinson, chemist, Talbot (late Back Creek):

and thanks him for "his letter of the 28th inst., and in reply begs to say that even as a temporary deposit the specimens will be received with great interest . . ."

Thus, although McCoy did not succeed in cadging the specimens for the National collection, in attempting to do so, he unwittingly identified the Back Creek from which they came; the creek of that name flowing through Talbot. Mr. Baragwanath, Director of the Geological Survey of Victoria, informs me that Talbot in the early mining days was always known as Back Creek. The entry in the catalogue of the 1861 Exhibition records the exhibit as: "212. Wilkinson, R. W., Back Creek—Geological Specimens, etc."

McCoy (10) figures a middle incisor of the upper jaw, which he says may belong to *D. longiceps*. In his explanation of the plate where he gives three aspects of it he describes it as "portion of the anterior incisor of the upper jaw of a *Diprotodon* from Back Creek" and figures the "lower tusk of *Nototherium*" also from Back Creek.

Back Creek has its source about 7 miles south-west of Talbot and flows over a wide flood plain in a mature valley set in undulating Ordovician country through the town of Talbot. Near the northern boundary of the town it passes on to a lava flow of the scoria cone phase that covers the Mount Greenock Lead, continues northerly on the lava for about 1 mile and is joined there by the Daisy Hill Creek; the confluent streams then flow in a lateral valley on the west side of the lava flow. Before the lava covered the Mount Greenock Lead, Back Creek joined the Lead about $2\frac{1}{2}$ miles north-east of Talbot. Most of the lava that covered the Lead came from the scoria cone of Mount Greenock. The lava covered the main valley but did not encroach far on the tributary valley of Back Creek, and there is no lava in that valley upstream from Talbot to its source. Mr. Baragwanath informs me that the lava across Back Creek's outlet dammed its waters and a lake was formed some distance upstream. This lake has been drained by a stream, now the lower part of Back Creek, cutting back southwards and breaching the dam.

In the Back Creek Valley upstream from the lava there are, then, two distinctive deposits—

- (a) Lacustrine silty black clay and impure diatomite, both newer than the Mount Greenock lava.
- (b) Fluvatile clays and sands that are older than the Mount Greenock lava.

The lacustrine beds rest on the fluvatile clays.

We do not know whether the *Diprotodon* remains came from "a" or "b." From what has been learned of the habits of *Diprotodon* in Victoria there is a strong presumption that they came from the lacustrine deposits. If, however, they came from the fluvial deposits, the depth is important, for while the surface fluvial beds are approximately the same age as the Mount Greenock scoria cone flow, the underlying beds as the depth increases become successively older.

7.—LAKE COLONGULAC.

Lakes Colongulac (Timboon), Corangamite, and Colac belong to what Grayson and Mahony (5) term the Colongulac type of lake: "these shallow basins appear," they state, "to occupy the natural depressions which occur between lava flows, and which have been deepened during times of drought by the wind blowing away the dry mud from their beds and increased in size by the action of the waves on their banks." Probably all the lakes of this type, which have no well-marked streams entering them and no outflow, started as shallow depressions filled with alluvium. The depressions were in the lava plain phase of the Newer Basalt and the Hampden Tuffs must have fallen in them if they were within range; tuffs falling in a depression presumably rest on alluvium or have been re-deposited as alluvium.

Bones of many marsupial genera have been found on the shores of Lake Colongulac, and Grayson and Mahony show on their Quarter Sheets (8 N.E. and 17 S.E. (New Series)) of the area "Bone Beds, *Diprotodon* Beds" on the shores of the Lake. The bone beds appear to be newer than the Hampden Tuffs, but most of the bones were found loose on the shores of the Lake and it is not certain whether they came from the bone beds, the Hampden Tuffs, or the re-deposited alluvium. There are no particulars of the beds from which a limb bone—a humerus presented by Dr. Greeves—and a leg bone in the Sweet Collection, both belonging to *Diprotodon*, came.

The succession in the district may be summarized—

- Alluvium.
- Dunes of redeposited Tuffs.
- Scoria cone basalts.
- Bone Beds. *Diprotodon* Beds.
- Hampden Tuffs.
- Buckshot Gravels.
- [Alluvium in old valleys and depressions].
- Newer Basalt (lava plain phase).

8.—COLAC.

The lower jaw with molars and incisors (Holotype No. 12109) of *Diprotodon longiceps* described by McCoy (10), the description of which is checked here, was obtained "in sinking a well in the Pliocene clays of Colac." An exhaustive search has revealed no additional facts about this important specimen. It may be assumed that the well was not deeper than 30 feet, and it is stated that the specimen was obtained in sinking it. The jaw is

fragile and shows considerable decalcification; the small amount of the containing bed adherent to it is light coloured and suggestive more of a Holocene sedimentary clay than a basaltic clay. It may have come from the Holocene surface beds immediately south of Colac; at any rate McCoy had not sufficient evidence when he described the specimen to say that the containing bed was Pliocene.

In the Sweet Collection at the National Museum there is a femur of a *Diprotodon* from Colac; a portion of the containing bed adherent to the specimen is a stiff basaltic clay quite unlike that on the holotype. In the Melbourne University collection there is a lower incisor of *D. australis*, also from Colac.

Some doubt has been cast on the validity of *Diprotodon longiceps* McCoy as a species. Stirling and Zietz (17) maintain "that while some of the Callabonna fossils certainly reveal the dental features of what [McCoy] has based his determination of [*D. longiceps*], we believe that we shall be able hereafter to show the characters in question do not amount to more than variations which are to be observed within the limits of Owen's original species." But McCoy bases his species on other characteristics besides the dentition. The measurements given by him (10) in his description and figures of the Holotype (No. 12109) differ and they have, for that reason, been checked. Since he examined the holotype, its anterior portion has been damaged; the measurements in his description must be accepted for the lower incisors and diastema, and it may be stated, incidentally, that where it is possible to check them, they have been found to agree. The following is his description (10), with the measurements converted to millimetres:—

Lower incisors: perfectly straight, with no trace of the upward curvature of *D. Australis* (Ow.); length 343 mm. (*D. Australis* only 254 mm.); circumference at emergence from socket (127 mm. from tip), 133 mm.; longitudinal extent of worn surface, 76 mm.; greatest width, 28 mm., being as long as but narrower and more oblique than, the same part of *D. Australis*; the wearing is in three planes corresponding to the three upper incisors opposed to it on each side; transverse section at point of emergence from socket oblong, with obtusely rounded angles; vertical diameter, 49 mm.; transverse diameter 37 mm.; outer side slightly concave longitudinally above the middle, other sides slightly convex; less than two thirds of the incisor is in socket, which extends backwards to vertical with line separating first molar with last premolar; surface of enamel with minute irregularly contorted vermicular longitudinal wrinkles and intervening irregular small pits and pores.

Diastema: From anterior upper edge of the incisor socket to second molar (D.4), 152 mm., and is consequently much longer than the corresponding part in *D. Australis*, which is only about 114 mm. and it rises at a much smaller angle (angle with incisor at socket 17° compared to 20°-30°) as it recedes from the incisor."

The posterior portion is undamaged and as it was when McCoy examined it. Check measurements (a) of the molars of both rami have been made, also (b) of McCoy's line figures (10) of molars . . . "natural size, viewed exactly from above, and

in profile for the greater convenience of more exact comparison with the figures of *D. australis* (Ow.), in Prof. Owen's Memoirs than the oblique views in the lithographic plates would permit . . . ,” and (c) from McCoy's printed description.

The first molar is missing.

(a) Check. Anterior-posterior measurements			(b) Line Block.	(c) Printed Description.
right ramus				
D4	28 mm.	left ramus	30 mm.	28 mm.
M1	44	43	44	44
M2	49	49	49	55
M3	53	55	52	58
Transverse measurements.				
D4	21	23	21	23
M1	28	28	29	28
M2	31	31	33	38
M3	35	37	36	38

There is closer agreement between (a) and (b) than between them and (c).

The following comparison is between *D. longiceps* (10) and *D. australis* (12):—

Age of Specimen.	<i>D. longiceps.</i>	<i>D. australis.</i>
	mature	fully grown
<i>Lower Incisors</i> —	perfectly straight.	nearly straight, upward curvature.
Length	343 mm.	254 mm.
Circum.	133	110
Dia. vert.	49	42
trans.	37	34
Socketed	2/3	2/3
<i>Diastema</i> —		
Extent	152	102
Angle with incisor	17°	20°–30°
<i>Molars</i> —		
Ant.-post.		
D3	missing	missing
D4	30	26
M1	44	47
M2	49	58
M3	52	61
Transverse		
D4	21	25
M1	29	36
M2	33	41
M3	36	41

McCoy (10) states that *D. longiceps* equalled in size *D. australis*, but this is doubtful. From the tips of the lower incisors to the hind portions of the last molars, the distance is, in *D. longiceps* 444 mm. and in *D. australis* 508 mm. Even with its longer incisors the distance is shorter in the first than in the second species; the distance occupied by the diastema and molars is 330 mm. in the first and 381 mm. in the second species, and thus commensurately shorter. Except D4, the molars of *D. longiceps* are all shorter in anterior posterior diameter, and there are noticeable differences in the transverse diameter. The distance between the rami opposite the third molar is in *D. longiceps* 70 mm. and in *D. australis* 95 mm.

Although the growth of the lower incisors was persistent, the fact that in *D. longiceps* (mature age) they were longer than in *D. australis* (fully grown) is of specific importance. The incisors were also straighter and worn in planes due to the characteristic set of the upper incisors, the diastema was less inclined and half as long again, the teeth were on the whole smaller and the distances between the rami shorter—these facts suggest a narrower head and that the animal is entitled to specific rank.

McCoy also records *D. longiceps* from Talbot (Back Creek), the Duck Ponds, and Limeburner's Point; it must be conceded, however, that the material from these localities is unsatisfactory.

9.—OMEQ.

As the exact locality of the Omeo specimens of *Diprotodon australis* Owen, *Nototherium victoriae* Owen, and *N. inerme* Owen is not given, it is not possible to fix their stratigraphical position. D. E. Thomas (19) discusses Lake Omeo and the three physiographical cycles incidental to the development of the Lake during which changes in the stream direction in the basin took place. "The Final Events have been," he states, "the deposition of the extensive alluvial flats in the lake basin and adjoining valleys; the formation of alluvial fans across the outlet of the lake; the building and subsequent breaching of the dune, and the reversal of the drainage from the north of the lake." In another place he says (19): "The effusion of lava dammed back the waters of Morass Creek and during this period the extensive flats were deposited. Morass Creek eventually cut through the barrier and formed a narrow gorge through which the lakes that were becoming silted up were drained. Lake Omeo is thus a relic of a more extensive lake system."

R. A. F. Murray (11) states that the basalt is part of the Older Basalt, that is its age is Lower Tertiary. On the Geological Map of Victoria (8 miles to an inch), however, its age is shown to be the same as the Newer Basalt in western Victoria and, since its configuration (*cf.* E. S. Hills) conforms to a lava infilled valley of the post-Older Basalt cycle of erosion, the map is probably correct. The lacustrine and fluvial beds of the Lake Omeo basin are, then, either Pleistocene or Recent.

10.—BUNINYONG.

In 1897 marsupial bones were found in the workings of the Great Buninyong Estate Mine, about 1½ miles south of Buninyong Railway Station. One of the fragments has the appearance of having been shaped by human agency and from that aspect has been widely discussed; it was stated by C. W. De Vis (20) to be "part of the distal half of a right rib, the seventh or eighth, of an animal so large that it could only have been one of the great *Nototheres* in all probability *Nototherium mitchelli* Owen."

T. S. Hart (6) described the bed in which the bone was found and its stratigraphical position. The containing bed was part of a lake deposit—a stratified black clay with much carbonaceous matter resting on a bouldery bed consisting of blocks of basalt

and Ordovician bedrock. The bones and the containing bed were pyritised; the bones themselves were much fractured. A small gutter below the black clay was worked in the mine until the gutter stopped abruptly against volcanic ejectamenta. Hart (6) suggests that the abrupt termination and the position of the ejectamenta are probably associated with an actual vent, and succession of vents, or the local subsidences in the neighbourhood of a volcanic vent. These would be explosive vents presumably through and subsequent to the Buninyong basalt, a flow belonging to the scoria cone phase. The gutter was that of the Devonshire Lead worked under the Buninyong basalt from several shafts. The stratigraphical position of the black clay is, therefore, above the gutter and below the Buninyong basalt.

Hart (6) says that the Buninyong basalt overlies the Yarrowee flow known at Ballarat as the "First Rock," another scoria cone flow. The Buninyong flow is the newest of the flows in the Ballarat District and judged by the amount of erosion was not in his opinion of any great age. He considers, however, that a considerable time elapsed between the Yarrowee and the Buninyong flows.

It appears, then, that the lake containing the *Nototherian* bone was formed by the damming of a creek, valley, or gutter by a lava flow, probably the Yarrowee flow, and as the bones were found in that part of the lacustrine clay resting on the bouldery bed above the gutter, they are slightly younger than the Yarrowee flow. Hart says that the bones are referable to "a comparatively recent period."

The Buninyong basalt is probably contemporaneous with some of the flows from the latest scoria cones in the Camperdown District and the Mount Greenock flow at Talbot.

11.—COIMADAI.

A. L. Coulson (3) mentions that with other marsupial remains found at Coimadai were "*Nototheriidae*: several bones not referred to any definite genus;" it is assumed, therefore that *Nototherium* occurs in these mammalian beds—the sands intercalated with the limestone, to which he ascribes a Pleistocene age.

The limestone, he states, was chemically precipitated in a small lake just before, during, and after the eruption of Mount Bullengarook, the lava flow from which filled the valley of the old Bullengarook River but did not encroach on the lake. He says that the basin containing the lake probably owed its origin to unequal consolidation of the underlying gravels but he mentions also, that it was possibly assisted by the damming of the River in its southern part, by one of the earlier flows of Newer Basalt. The second possibility suggested by him seems to be more plausible for it is difficult to envisage the formation of such a lake unless it was dammed by a lava flow. A fault—the Djerriwarrh Fault—is stated to cross the lower reaches of the Bullengarook River near the limestone but its reputed downthrow side is to

the south: it played no part in the damming. The scoria cone flow from Mount Bullengarook was preceded by the accumulation of fine ash in the Lake basin.

The limestone is later than the Newer Basalt: the Lake existed before, during and after the Mount Bullengarook scoria cone flow. The causes that lead to the formation of the Lake are seemingly similar, in some respects, to those responsible for the Duck Ponds Lake.

12.—WATCH HILL (?).

The records of the National Museum of specimens (Nos. 1895-6 and 2284-5) identified by McCoy (10) as *Nototherium mitchelli* Owen from "Murchill Station" have lost much of their value owing to the uncertainty regarding the locality. Concerning the specimens, which were obtained in 1865, the Museum Register gives the following information:—"Murchill Station (J. Bell) presented by—Dyson per Hon. Dr. Greeves." On August 26, 1865, McCoy published the following letter in "The Australasian":—

"I beg to announce in your columns a very interesting addition to the National Museum collection, which we owe to the kind offices of Dr. Greeves . . . The present addition is a small series of four specimens found at Murchill Station (belonging to Mr. John Bell) presented by Mr. Charles Dyson, of Market-square, Geelong, through Dr. Greeves . . ."

Although a number of authorities have been consulted and old papers and plans of the many properties owned by John Bell, a well-known Western District pastoralist, have been examined, all efforts to locate "Murchill" Station have been unavailing. Mr. J. Maxwell Bell of Golf Hill, Shelford, a member of the family, states that he has never heard of such a place in connexion with the pastoral holdings of John Bell and expressed the opinion that "Murchill" is Watch Hill, formerly owned by John Bell. There is little doubt that "Murchill" is an error: Mr. J. Maxwell Bell's opinion is probably correct.

That bone beds were known at an early date near Lake Corangamite to which the pastoral holding of Watch Hill had a frontage is shown by the following extract of a letter from E. C. Hobson (8) to R. C. Gunn of Launceston in 1854 on *Diprotodon* and mentioning an extensive bone deposit near the Lake:—

"I have received a specimen of the distal end of one of the metatarsal bones of some large animal from (Lake Corangamite). The fragment is completely fossilised, and from a hard clay cliff on a salt lake beyond Lake Colac. The same person found a large bone, a femur, eight or nine inches in diameter at the upper end and 4 inches in the middle of the shaft."

The salt lake mentioned by Hobson was probably on the Watch Hill holding, which is shown on the 8 mile Geological Map of Victoria near the north-eastern shore of Lake Corangamite between Beecac and Cressy. It was wholly on the lava plain phase of the Newer Basalt and within its former boundaries were a number of lakes and swamps. The Woody Yallock Creek flows through it.

Stratigraphical Position of the Diprotodontidae.

The containing beds of the *Diprotodontidae* have been dealt with in the foregoing pages in respect to the following localities:—

1. North Melbourne .. *Diprotodon australis* Owen.
2. Footscray .. *Diprotodon australis* Owen.
3. Duck Ponds .. *Diprotodon longiceps* McCoy.
4. Limeburner's Point .. *Diprotodon longiceps* McCoy.
5. Lancefield .. *Diprotodon australis*, *Nototherium* sp.
6. Talbot .. *Diprotodon longiceps*, *Nototherium* sp.
7. Lake Colongulac .. *Diprotodon* sp.
8. Colac .. *Diprotodon longiceps*, *D. australis*.
9. Omeo .. *Diprotodon* sp., *Nototherium victoriae* Owen,
N. inerme Owen.
10. Buninyong .. *Nototherium* sp.
11. Coimadaí .. *Nototherium* sp.
12. Watch Hill .. *Nototherium mitchelli* Owen.
13. Melton .. *Notherium* sp.

The stratigraphical positions ascribed to the containing beds and their relationship to the succession of the fluvial deposits as worked out by Keble and Macpherson are as follows:—

Age.	Maribyrnong River Cycles.	Maribyrnong River Phases.	Localities.
Recent	Present Cycle	{ Recent	1, 2, 6, 9, 10.
		{ Maribyrnong Terrace	
Upper Pleistocene	{ Maribyrnong Cycle	{ Maribyrnong Flood Plain	{ 5, 7, 11, 12.
		{ Braybrook Terrace	
	{ Braybrook Cycle	{ Braybrook Flood Plain	
		{ Keilor Terrace	{ 3, 4, 13?
	{ Keilor Cycle	{ Keilor Flood Plain	
Middle-Lower Pleistocene	{ NEWER BASALT (lava plain phase).		

The stratigraphical positions of 1, 2, 3, and 4 are considered accurate, 6, 9, and 10 approximate, and 5, 7, 11, and 12 are placed within wide limits.

All the species came from deposits newer than the lava plain phase of the Newer Basalt and all are of Upper Pleistocene age.

Habitat of the Diprotodontidae.

Including King Island, nine of the containing beds are of lacustrine origin, three are of fluvial origin, and one is from a spring deposit. There is no doubt, therefore, that the *Diprotodontidae* preferred a terrain with lakes and swamps, or near rivers and springs. They were adapted to a mode of life in these surroundings and it is unlikely that they would be easily bogged, although this is the reason usually assigned for their remains being found in association with such deposits. Bogging

casts a doubt on their adaptability to their environment; their feet were formed for an existence in swampy and marshy places, both hind and front feet were plantigrade, and their muscles, judged by the attachments, were strong.

Lake Callabonna, South Australia, where complete skeletons were found is described by E. C. Stirling (16) as a great flat clay pan covered at places with dunes and drift sand. The water is salt and there are a number of brackish springs issuing from its bed. The surface bed is a stiff yellowish clay containing much sharp sand, resting on a layer of unctious blue clay—the bone bed—about 2 feet thick, which overlies a bed of coarse sharp sand beneath which is a blue clay similar to the second bed. The position and attitude of the skeletons and the frequent approximation of the bones is, Stirling contends, strongly suggestive of death in situ after being bogged, which is supported too, he maintains, by the fact that the feet of the skeletons are most deeply buried. Conceding the possibility of their having been bogged, as Stirling suggests, it is difficult to understand why they were attracted by a salt lake. The question presents itself, was Lake Callabonna salt when the animals were bogged? W. Howchin (9) states that the Lake is portion of the dead Frome River System that found its way [probably in the Pleistocene] to the southern coast but “it is doubtful whether any examples of this extinct fauna *Diprotodon*, etc., have been discovered in the older north to south river channels.” The saline conditions are a result of a change of climate to the present arid conditions—a change from a wetter and fertile period to the present aridity. G. Scouler (15) states: “as to the appearance and extension of the *Diprotodon australis* and similar congeners . . . it was a greater annual rainfall which Australia enjoyed that ushered in these creatures upon the scene. A greater rainfall implies that a more exuberant vegetation than we now possess was spread over the landscape, and following the law of evolution, a race of animals in every way more powerfully developed is evolved to utilize it.”

Much the same problem arises in connexion with the remains found in Victoria near salt lakes such as those in the Western District. It is true that none of these remains have been definitely associated with saline deposits, but the lakes are now salt: were they always so? Previous to the present period of small inflow, insufficient in most cases to keep the lake from becoming salt and periodically drying up was there a wetter climate during which there was a greater inflow supplying the lakes with sufficient water to balance evaporation—a period when their waters were fresh or perhaps brackish? If so did this period coincide with the last glacial period? It is an interesting fact in this connexion that the North Melbourne and Footscray beds containing *Diprotodon* were according to Keble and Macpherson deposited at the close of the last glacial period (W3).

The probable habitat of the *Diprotodontidae* is well pictured by Mr. J. Graham Haines in his letter (*infra*) describing Egg Lagoon, King Island, in its undrained state. King Island has been affected less by the arid conditions of the mainland and Egg Lagoon must have represented a close approach to the natural habitat of these marsupials.

Occurrence of *Diprotodon* on King Island.

A record of *Diprotodon* from King Island not only fixes the southernmost limit of its migration—it is not found in Tasmania—but gives us some idea when the land bridge connecting Australia with King Island, and incidentally Tasmania, was broken.

In 1927 the National Museum received from Mr. J. Graham Haines a molar (No. 14403) of *D. australis* from Egg Lagoon, King Island, from what is recorded as a sub-Recent Deposit. This is the only record of *Diprotodon* south of the mainland; Scott and Lord (14) have, however, recorded *Nototherium victorise* Owen from "swamp lands" on the Island.

Mr. Haines's information as to the precise locality is given in the following excerpts from his letter of June 19, 1944, which also contains an instructive description of Egg Lagoon in its undrained state:—

"Quite a lot of teeth and jaw bones with teeth in them were found by men I have employed in excavating a drain through my property on Egg Lagoon in the north of King Island. In a distance of about a quarter of a mile, teeth and jaw bones were found in three different spots . . . The allotment on which the teeth were found is a 500-acre block in the name of J. Haines, 34/28. To the west of this block you will see it is joined by two blocks, one in the name of Holland and Haines, and the other in the name of C. Wilshire. Take the boundary of these two blocks which is the main Egg Lagoon drain, extend it half a mile, just a shade south of due east, and you will have the approximate place where the teeth were found. The drain was approximately 4 feet deep. The tooth was found in clay underlying rich black swamp soil.

Egg Lagoon (the name is misleading) before it was drained was an area of low country that was under water during the winter and early summer . . . it grew the usual plants found on shallow swamps; it was soft and boggy at all times, particularly where it joins the sand and limestone country to the west. To the east, the land was slightly higher and covered with very big Paper Bark Ti Tree; it was in this country that the teeth were found. Before the drain was put through, there was more or less a natural water course, not washed out or anything, just a foot or so lower than the rest of the flat; it was covered with the same big Paper Bark Ti Tree and could not be picked out till the levels were taken . . ."

The fauna and flora of King Island is Tasmanoid, not Australoid. It is probable that the break of the land bridge connecting it with Tasmania occurred late in the subsidence of Bass Strait, and the fauna and flora has changed little. *Diprotodon* is a continental form and, since it has not been found in Tasmania, must have migrated to King Island by a land bridge connecting that Island with Australia. A reconstruction of the floor of Bass Strait from the bathymetrical contours indicates that this land

bridge joined the Island on its east coast, the connexion being through the Mornington Peninsula on the mainland; it is improbable that there was ever a connexion through Cape Otway. The Mornington Peninsula-King Island land bridge was intact when *Diprotodon* first appeared in Victoria, i.e., in the early Upper Pleistocene or late Middle Pleistocene.

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ART III.—*Note on the Age and Palaeogeography of the Brown Coal Deposits of Gippsland, Victoria.*

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Contents.

INTRODUCTION.

BORES FROM WHICH SAMPLES HAVE BEEN EXAMINED.

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PROBABLE AGE OF THE BROWN COALS AND THE ORIGIN OF THE MICRO-FAUNA CONTAINED THEREIN.

Abstract.

Marine micro-fossils including foraminifera, bryozoa and ostracoda were found in the lignitiferous beds referable to the Anglesean Stage (Middle Miocene), in deep bores in East Gippsland. Later they were discovered in lignitiferous material from bores drilled to prove the extent of the bauxite in the parishes of Mirboo and Budgerie and of the brown coal deposits in the parishes of Loy Yang, Maryvale and Hazelwood. Based on stratigraphic evidence provided by these fossils, it is suggested that the brown coals of the Yallourn formation accumulated during the Middle Miocene, Upper Miocene and probably basal Lower Pliocene.

Introduction.

Following the record by the writer (1943) of a micro-fauna in the lignitiferous clays and sandstones underlying the marine deposits in numerous deep bores in East Gippsland, it was decided to investigate the lignites and sediments associated with them, in the Traralgon, Morwell, Mirboo, and Budgerie areas.

A series of bores has been drilled by the Commonwealth and Victorian Governments in the Mirboo and Budgerie areas to prove certain of the bauxite deposits there. These bores revealed that, in places, lignites are interbedded with the clays and sands which overlie the bauxite. A microscopic examination of samples of this lignitiferous material showed the presence of a small micro-fauna consisting of minute foraminifera and fragments of bryozoa, indicative of Middle Miocene to lower Upper Miocene age.

In view of this discovery, the State Electricity Commission of Victoria was asked by the Mineral Resources Survey to supply samples of the Yallourn Formation (Crespin, 1943) met with in bores put down to test the brown coal deposits in the Morwell and Traralgon districts. The Commission kindly complied with this request and samples have now been examined from bores in the parishes of Maryvale, Hazelwood, and Loy Yang. As a result a micro-fauna has been found. In preparing these samples for micro-examination every precaution was taken to avoid the inclusion of any adventitious material. That this fauna is indigenous to the lignitiferous beds is supported by the similarity of forms and by the manner of preservation of the fossils.

Bores from which Samples have been Examined.

(1) BORES TO PROVE THE BAUXITE DEPOSITS.

PARISH OF MIRBOO.

- (a) Bore No. 27, from 26 feet to 36 feet, and 14 feet above the bauxite.

PARISH OF BUDGEREE.

- (b) Bore No. 15, from 105 feet to 110 feet, and 15 feet above the bauxite.
- (c) Bore No. 16, from 103 feet and 26 feet above the basalt. (No bauxite was recorded from this bore).
- (d) Bore No. 18, from 89 feet to 90 feet, and 14 feet above the bauxite.

(2) STATE ELECTRICITY COMMISSION BORES TO PROVE BROWN COAL.

PARISH OF HAZELWOOD.

- (e) Bore No. 31 at depth of 335 feet. (Mr. J. M. Bridge of the State Electricity Commission notes that this sample is apparently from below the Morwell No. 1 seam.)

PARISH OF MARYVALE (MORWELL).

- (f) Bore No. 153, from 238 feet to 240 feet below surface. (This sample is 125 feet above the Morwell No. 1 seam and is probably in the Yallourn seam.—J.M.B.).

- (g) Bore No. 155.—First sample at 546 feet below surface. (8 feet below Morwell No. 1 seam, which is 500 feet thick at this locality. Sample was taken between two seams of coal each 3 feet thick.—J.M.B.).

Second sample at depth of 552 feet. (14 feet below Morwell No. 1 seam and 14 feet above No. 2 seam, which is here 189 feet thick.—J.M.B.).

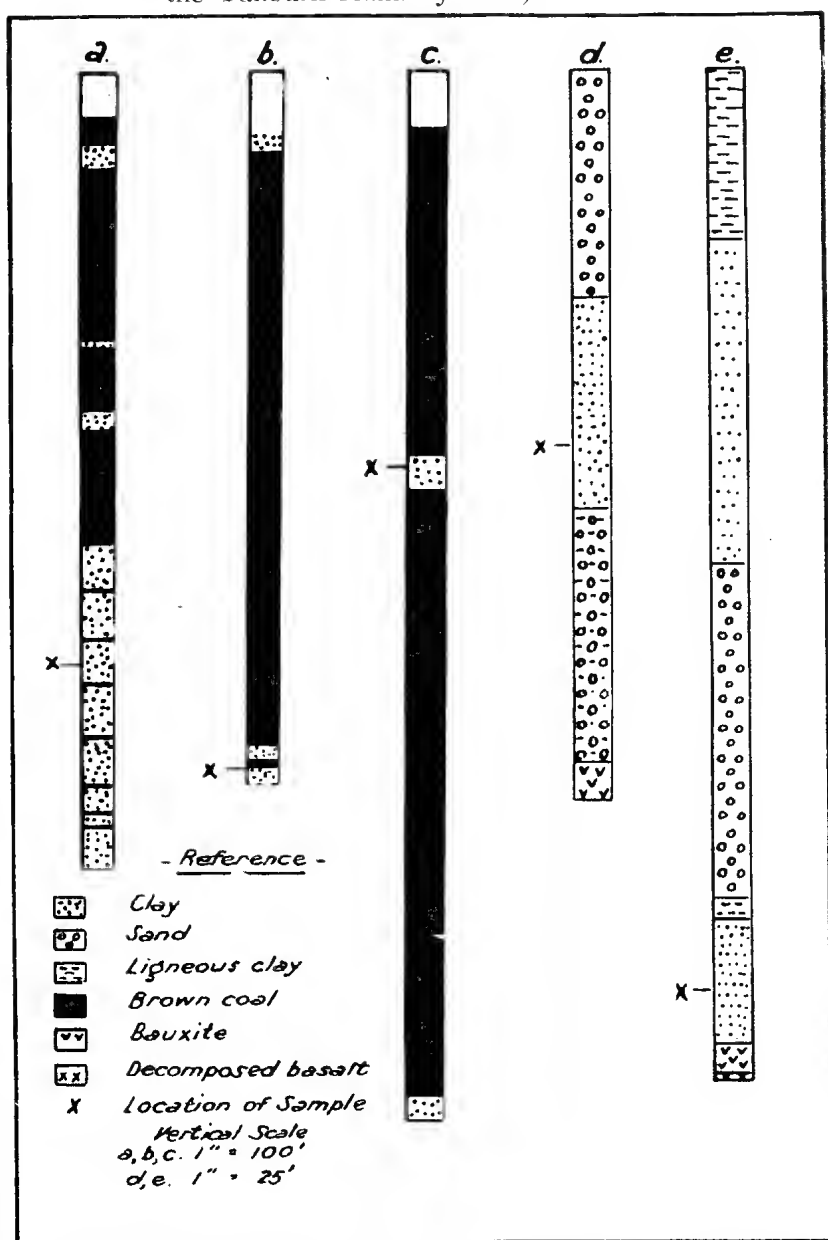
- (h) Bore No. 169, from depth of 312 feet. (86 feet below Yallourn seam and 30 feet above Morwell No. 1.—J.M.B.).

- (i) Bore No. 171.—First sample from 363 feet to 364 feet below surface. (Immediately below Yallourn seam, which is here 301 feet thick.—J.M.B.).

Second sample 558 feet to 560 feet below surface (17-19 feet below Morwell No. 1 seam, which is 78 feet thick at this locality.—J.M.B.).

PARISH OF LOY YANG (TRARALGON).

- (j) Bore No. 84, from 26 feet below surface.
 (k) Bore No. 86, from 597 feet below surface.
 (l) Bore No. 92, from 193 feet below surface.
 (m) Bore No. 96, from 99 feet below surface. (26 feet below a 36-ft. seam, which probably corresponds to the Yallourn seam.—J.M.B.).



TEXT FIG.—Diagrammatic sections of bores. a. No. 109, Ph. Loy Yang, S.L. 240'; b. No. 31, Ph. Hazelwood, S.L. 235'; c. No. 92, Ph. Loy Yang, S.L. 200'; d. No. 27, Ph. Mirboo, S.L. 650'; e. No. 15, Ph. Budgerie, S.L. 1050'.

- (n) Bore No. 103 at depth of 300 feet.
- (o) Bore No. 109.—First sample from 257 feet; second sample at 295 feet below surface. (65 feet below the last major seam met. It probably corresponds to an horizon immediately below the Morwell No. 2 seam.—J.M.B.).

Distribution of Fossils in the Bores.

The following table lists the fossils noted in the bores detailed above. The letter designations used in the table are the same as those given in the foregoing list:—

Fossils.	Bores.													
	a	b	c	d	e	f	g	h	i	j	k	l	m	n o
FORAMINIFERA—														
Anomalina glabrata Cushman ..	—	—	x	—	—	x	—	—	—	—	—	—	—	—
Anomalina sp. 1	—	—	—	—	x	—	—	—	—	—	—	—	—	—
Astrononion australe Cushman	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Cibicides cf. victoriensis Chapman, Parr & Collins ..	—	—	—	—	—	—	—	x	—	—	—	—	—	—
Cyclammina sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	x
Eponides sp.	x	x	x	x	—	—	x	x	—	x	—	x	—	—
Elphidium crespinae Cush. ..	—	x	—	—	—	—	—	—	—	—	—	—	—	—
Elphidium sp.	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Globigerina bulloides d'Orb. ..	—	—	—	x	—	—	x	—	—	—	—	—	—	—
Globigerinoides trilobus (d'Orb.)	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Globorotalia cf. canariensis (d'Orb.)	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagena sulcata (W. & B.) ..	—	—	x	—	—	—	—	—	—	—	—	—	—	—
Marginulina glabra d'Orb. ..	—	—	—	—	—	—	x	—	—	—	—	—	—	—
Planulina wuellerstorfi (Schw.)	x	—	—	—	—	—	—	—	—	—	—	—	—	—
ANTHOZOA—														
Mopsea tenisoni Chapman ..	—	x	x	x	—	—	—	—	—	—	—	—	—	—
BRYOZOA—														
Cellaria sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	x
Crateropora patula (Waters) ..	—	—	—	—	—	—	x	—	—	—	—	—	—	—
Filisparna orakiensis Stol. ..	—	—	x	—	—	—	—	—	—	—	—	—	—	—
Hornera sp.	—	—	x	—	—	—	—	—	x	—	—	—	—	—
Idmonea milneana d'Orb. ..	—	—	x	—	—	—	—	—	—	—	—	—	—	—
Membranipora macrostoma (Reuss)	—	—	—	—	x	—	—	—	—	—	—	—	—	—
Retepora rimata Waters ..	—	—	x	—	—	—	—	—	—	—	—	—	—	—
Retepora sp.	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Scuticella sp.	—	—	x	—	—	—	—	—	—	—	—	—	—	—
Bryozoa indet.	—	—	x	x	—	x	x	—	x	—	x	—	—	x
OSTRACODA—														
Aglaia clavata G.S.B.	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Alatacythere praeantarticum (Chapman)	x	—	—	—	—	—	—	—	—	—	—	—	—	—

Samples from Loy Yang Bores, 96 (m) and 103 (n) contained no fossils.

Notes on the Fossils.

The majority of the fossils listed above are poorly preserved; many of the bryozoa are indeterminate. The fine pores are frequently filled with minute particles of lignitiferous material.

The most important foraminifera of zonal value found in the above bores are *Cyclammina* sp. and *Anomalina* sp. 1, the former being characteristic of the Anglesean Stage (Middle Miocene) and the latter of the Mitchellian Stage (Upper Miocene). (Crespin, 1943.)

Cyclammina is represented by several small, moderately well preserved tests in Loy Yang Bore No. 109 at 295 feet. The Anglesean Stage as represented in bores in East Gippsland, where it underlies rich fossiliferous marls referable to the Janjukian Stage, is not typical of the deposit as found at the type locality at Anglesea in Western Victoria, and it is in consequence of this facies change that the writer (1943) instituted the term "Yallourn formation" for the Gippsland equivalent. She has given the stratigraphic range of *Cyclammina* from the Anglesean Stage up to the Batesford substage of the Balcombian. Except for one record in Sector II. (Providence Ponds), the occurrence of the genus in the Batesford substage is restricted to the deep bores in Sector IV. (Ninety Mile Beach.) In view of this extended stratigraphic range of the genus, it may be unwise to assume that the sample in which *Cyclammina* was found is definitely referable to the Anglesean, but from information available it seems that it came from an horizon low in the Yallourn formation.

The species referred to as *Anomalina* sp. 1 in the Hazelwood Bore No. 31 at 335 feet, has a restricted stratigraphic range. In the Gippsland bores and in the Lakes Entrance Oil Shaft, the species does not occur in a downward direction below the top part of the Middle Miocene, i.e., the Bairnsdale substage of the Balcombian. It is the characteristic species of the Mitchellian Stage (Upper Miocene) and ranges into the basal portion of the Kalimnan Stage (Lower Pliocene).

Cibicides cf. *victoriensis*, *Astronion australe*, and *Elphidium crespinae*, although typical of the Balcombian Stage in Gippsland as well as in other parts of Victoria, have an extended vertical range in Gippsland. *A. australe* is recorded from the Anglesean up to the Kalimnan, where it is fairly common in the basal portion. *C. victoriensis* and *E. crespinae* range from the Anglesean to the Mitchellian, but their characteristic development is in the Balcombian.

Joints of *Mopsea* are common throughout the Balcombian Stage in Gippsland.

All the specimens of bryozoa are poorly preserved. They are all chalky white in appearance and very fragmentary. The assemblage of species is typical of the Middle and Upper Miocene deposits of Gippsland.

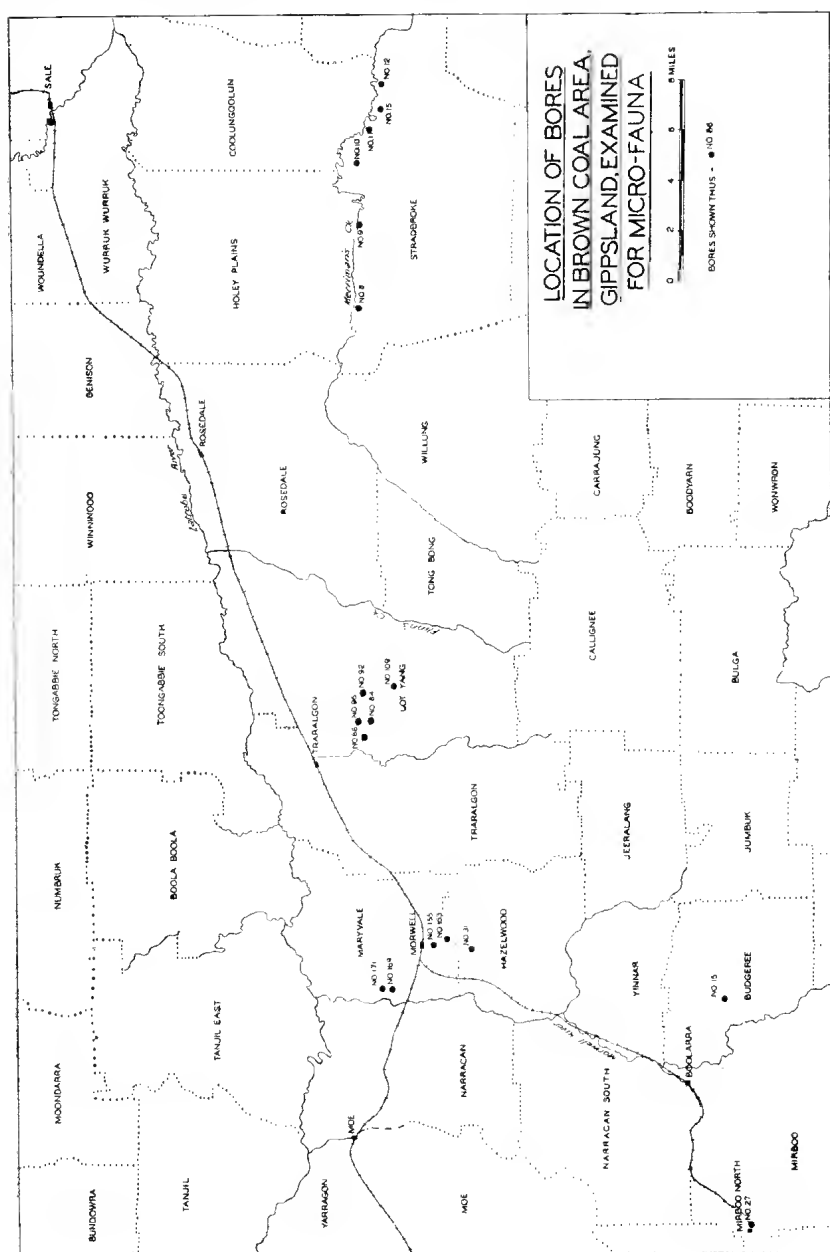
Probable Age of the Brown Coals and the Origin of the Micro-Fauna Contained Therein.

Consideration of the Tertiary stratigraphy, based on the examination of samples from the bores listed above and of numerous sections of deep bores east, south, and south-east of the brown coal deposits, suggests that the brown coals of Gippsland accumulated over a considerable period of time. The basal portion of the Yallourn formation is represented by the Anglesean Stage, which, east of a line running north from the western portion of Ph. Stradbroke through the parishes of Coolungoolun, Wurruk Wurruk, and Bundalagualh to Ph. Stratford, has been proved by boring to underlie the marine fossiliferous beds of the Janjukian Stage. West of that line there was apparently a period of accumulation of material in lakes which lasted from Anglesean times (Middle Miocene) until the close of the Upper Miocene (Mitchellian Stage) or opening of the Lower Pliocene (Kalinman Stage). It is suggested that the brown coals accumulated during this period. During the deposition of the fossiliferous beds to the east, there was some oscillation of the sea-floor bringing about a rise in sea-level. The result was a slight flooding of the lakes to the west by waters containing a few marine forms which were subsequently deposited in the lignitiferous sands.

The above suggestion as to age of the brown coals is substantiated by the presence of the typical Anglesean foraminifer, *Cyclammina*, in the sample from Bore No. 109, Ph. Loy Yang, which is the most easterly bore to be examined and which is situated nearer than the other bores to the main Gippsland Basin described by the writer (1943), and the presence, in Bore No. 31, Ph. Hazelwood, of *Anomalina* sp. 1, which does not appear in the stratigraphic section until the top of the Balcombian stage and which ranges through the Mitchellian to basal Kalinman.

It is estimated that the brown coals are about 1,000 feet thick in the Morwell and Yallourn areas, with the Morwell No. 2 seam representing the lowest horizon. Foraminifera typical of the Anglesean Stage are present (in the Loy Yang Bore No. 109) in the lignitiferous clays which underlie this seam. It is quite probable that certain seams of brown coal in this portion of the area may be correlated with those which occur in many of the deep bores south and east of Sale. In these bores, seams of brown coal were encountered in the Anglesean Stage at considerable depths below the marine fossiliferous beds referable to the Janjukian. A seam 60 feet thick was present in the Sperm Whale Head Bore (Ph. Poole Poole) between the depths of 2,739 and 2,789 feet; 90 feet of brown coal were recorded from the Lake Kakydra Bore (Ph. Nuntin) between 3,041 and 3,131 feet; seams of varying thicknesses occurred in the Holland's Landing Bore (Ph. Bengworden South) and in the Sale Bore (Ph. Wurruk Wurruk). A micro-fauna was found throughout the Anglesean in all these bore sections.

In the lignitiferous clays and sands from bores in the Mirboo and Budgeree areas and in all bores examined in the Morwell and Traralgon areas, except Loy Yang, No. 109, the micro-fauna is typically Balcombian and Mitchellian.



Information derived from the Victorian Boring Records and personal investigation of many bores in the area, indicate that no marine sediments as developed in the Janjukian, Balcombian, and Mitchellian Stages east of a line drawn north from No. 3 Bore, Ph. Darriman through No. 8 Bore, Ph. Stradbroke on Merriman's Creek, along the western boundary of Ph. Coolungoolun to the La Trobe River, thence to the western portion of Ph. Stratford, are known west of that line. A geological section drawn in an east-south-easterly direction from No. 8 Bore, Ph. Stradbroke through other bores along Merriman's Creek to No. 14 Bore, Ph. Giffard, at Seaspray on the Ninety Mile Beach, a distance of about 20 miles, illustrates the gradual thickening, in that direction, of the marine Tertiaries. No. 8 Bore, Ph. Stradbroke, reached the brown coal at 3 feet below the surface, after passing through a few feet of the "Torrent Gravels" of Gippsland. No. 9 Bore, in the same parish and about $1\frac{1}{2}$ miles to the east of No. 8, penetrated the marine fossiliferous beds (probably Janjukian in age) at 32 feet, and struck brown coal at 222 feet. The thickness of the marine beds increases rapidly east of this bore, until in No. 14 Bore, Ph. Giffard, they had not been bottomed at 1,600 feet when drilling ceased, the bore then being in beds referable to the Batesford substage of the Balcombian.

The country north of No. 8 Bore, Ph. Stradbroke to the La Trobe River and west through the parishes of Holey Plains and Rosedale to Moe, has been intensively drilled to prove the extent of the brown coals, but no marine fossiliferous beds have been encountered.

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The diagrammatic sections of bores shown in Text-figure 1, have been compiled from bore logs supplied by the Mineral Resources Survey, Canberra and the State Electricity Commission of Victoria.

A map showing various parishes in which the bores examined for micro-fauna are located, is attached. The bore sites in Ph. Stradbroke mentioned in the text, are also included.

ART IV.—*Australian Ambrosia Fungi.*

(*Leptographium Lundbergii* Lagerberg et Melin, and *Endomycopsis* spp. Dekker.)

By SHIRLEY WEBB

(communicated by Dr. Ethel McLennan).

[Read 9th November, 1944; issued separately 10th December, 1945.]

Abstract.

1. The fungus *Leptographium Lundbergii* and two species of sporogenous yeasts belonging to the genus *Endomycopsis* were isolated constantly from the tunnels of the Australian ambrosia beetle, *Platypus subgranosus* in Myrtle beech, *Nothofagus Cunninghamii* and two other Australian timbers.

2. The characteristic features of *L. Lundbergii* are described in detail and compared with those of ambrosia fungi studied by other workers. The conclusion is reached that ambrosia fungi from different parts of the world belong to the same genus *Leptographium* and probably in many cases to the above-mentioned species. The first name associated with an ambrosia fungus was that of *Monilia candida* Hartig, but reasons are given why the fungus should not be placed in this genus.

3. The work of other authors connecting the conidial stage *Leptographium Lundbergii* with the ascigerous stage *Ceratostomella* is discussed and an affinity suggested between the Australian form and the species *Ceratostomella ips*.

4. The two species of *Endomycopsis* are described as Forms A and B. The frequent association of yeasts with wood-inhabiting beetles is mentioned and the question whether they serve the beetles directly as food or assist indirectly by stimulating the growth of the other fungus is discussed.

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3. ACCOUNT OF *Leptographium Lundbergii*.
 - A. Nomenclature.
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 - D. Comparison with other Ambrosia Fungi.
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4. RELATIONSHIP OF *Leptographium* WITH THE GENUS *Ceratostomella*.
5. THE ASSOCIATION OF *Ceratostomella* WITH THE AUSTRALIAN AMBROSIA FUNGUS.
6. ISOLATION OF YEASTS FROM THE TUNNELS OF *Platypus subgranosus*.
7. ASSOCIATION OF YEASTS WITH WOOD INHABITING BEETLES.
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Introduction.

It has been recognized for the past century that beetles belonging to the group of wood-boring insects known as Ambrosia beetles, cultivate in their galleries a fungous crop upon which they, and their larvae, subsequently feed. The beetles themselves have received considerable attention and have been described accurately, whereas comparatively little mycological work has been done on the associated fungi.

Specimens of the timber of myrtle beech, *Nothofagus Cunninghamii*, which had been attacked by the Ambrosia beetle *Platypus subgranosus*, were submitted to the Botany Department of the Melbourne University and many cultures were made from the wood immediately surrounding the galleries of the beetle, and resulted in the constant isolation of one fungus and two types of sporogenous yeasts. The fungus was identified as *Leptographium Lundbergii*, Lagerberg et Melin, and the yeasts as species of the genus *Endomycopsis* Dekker. Cultures from the beetles themselves and from larvae taken from the galleries also gave the same forms.

Isolations from the galleries of the beetle in two other Australian timbers, Mountain Grey Gum, *Eucalyptus goniacalyx* and Mountain Ash, *E. regnans*, helped to confirm the constant association of *Leptographium Lundbergii* and the *Endomycopsis* spp. with *Platypus subgranosus*.

Method of Isolation.

In making isolations from the beetle galleries, a block of infested timber, preferably with larvae or beetles still present, was taken and sterilized superficially with mercuric chloride solution. The block was then split with a sterilized tomahawk in order to expose portion of the gallery or tunnel. Small slivers of the timber at the blackened edge of the gallery were removed with sterile chisel forceps and transferred to malt agar plates. The plates were left in the laboratory at room temperature during the warmer months of the year, but during the winter were incubated at 25°C. Appreciable growth of the associated organisms took place within four or five days.

Account of *Leptographium Lundbergii*.

NOMENCLATURE.

Leptographium Lundbergii is the type species of the genus *Leptographium* Lagerberg et Melin, created and described by Lagerberg, Lundberg and Melin (14) for a fungus which they isolated from a trunk of *Pinus sylvestris* showing intense blue-staining. This organism is now known to be a common cause of blue-stain in conifers and it has also been recorded by Verrall (28) as a lesser staining fungus of hardwoods in America.

Lagerberg and Melin emphasized when they created the genus, as did Grosmann subsequently, that *Leptographium* was in all probability identical with the genus *Scopularia* Preuss. *Scopularia venusta* was the name given by Preuss (18) to a blue-staining fungus which he found on decorticated pinewood in 1851. No spore measurements or details were given and the conidiophores were apparently falsely pictured. They were shown to be branched in a penicillate fashion and the individual branches to be septated. However, the curious manner in which the bases of the branches were extended across the main stalk of the conidiophore in a collar-like fashion looks very unreal. Saccardo doubted the fidelity of the reproduction, and as the fungus was not found again, it seems better to adhere to the later genus *Leptographium* rather than to the somewhat uncertain *Scopularia*.

Goidanich (7), a later worker, preferred the use of *Scopularia* to *Leptographium* and transferred *L. Lundbergii* to that genus.

GROWTH CHARACTERISTICS.

On malt agar, the fungus is fast growing, covering a 9 cm. Petri dish in four to five days. At first, it is sparse and white with very long aerial hyphae. In an inverted petri dish culture, these aerial hyphae reach right down from the surface of the agar to the lid as fine strands. In the majority of cultures, the white mycelium soon acquires a rather powdery appearance due to the formation of abundant conidia.

As the culture ages, the mycelium gradually darkens, while the medium changes colour more rapidly and passes through various shades of brown, from Brussels Brown, Raw Umber, and Cinnamon Brown to Fuscous Black or Chaetura Black (Ridge-way Colour Standards and Colour Nomenclature). The aerial hyphae tend to flatten out very soon with the collection of drops of honey-coloured liquid and the surface of the culture appears moist or even sodden.

After a period of time, varying from about two weeks to two or more months, round yellowish-brown yeasty spots, up to 5 mm. in diameter, appear in many though not all of the cultures, and it is in these that the typical conidia and conidiophores of *Leptographium* are found clustered together.

After subculturing for some time, more aerial mycelium may be formed and the surface of the culture is then quite woolly, losing its yeasty or sodden appearance.

As the cultures commence to change in colour and become brown, microscopic examination shows the formation of yellow to dark-brown hyphae, twisted in loose strands, both in the aerial

and submerged mycelium. Very wide brown hyphae, 10μ or more in diameter, also make their appearance and are characteristic.

The conidia are hyaline and unicellular and are extremely variable in shape and size. Those formed in very young cultures are as a rule oval or nearly cylindrical and may be from about 2 to 16μ in length (fig. 1A). Those formed later on the mature



FIG. 1A.—Conidia from a young culture of *Leptographium Lundbergii*. $\times 960$.

conidiophores are usually somewhat truncate and less variable in size, the average for 100 conidia being 8.9μ by 5.3μ with a range from 4 to 15μ by 3 to 7μ (fig. 1B).



FIG. 1B.—Conidia from a mature conidiophore in an old culture. $\times 960$.

The mode of formation of the conidia varies considerably according to the age of the culture. At first, they are borne singly on the tips of the hyphae and on short branches along the

main hyphae (fig. 2). The conidia tend to adhere together in mucous and form small round heads. This can be readily observed if the fungus is grown on a clear medium, when the spore heads

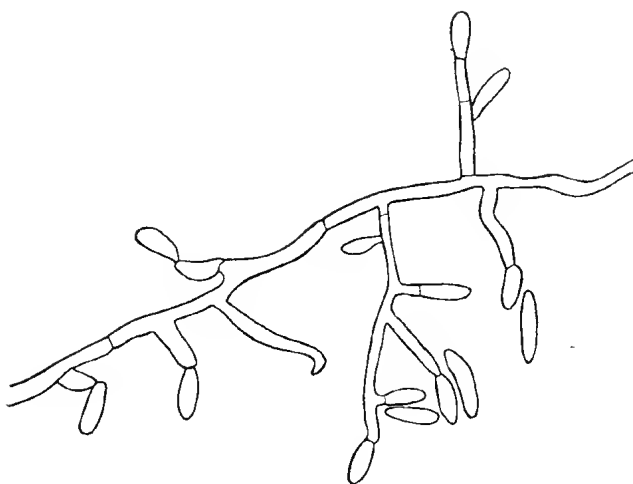


FIG. 2.—Early stage in conidial formation. \times approx. 720.

can be seen in situ through the agar (fig. 3). In this stage, a strong resemblance to the genus *Cephalosporium* is shown, and if the later mode of conidial development were not observed, the

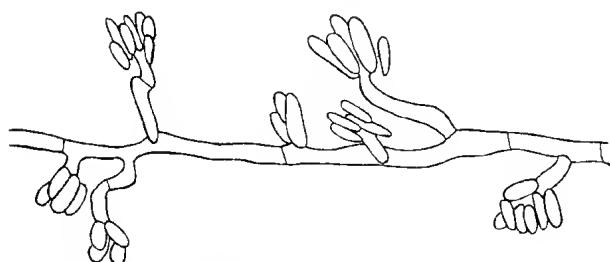


FIG. 3.—*Cephalosporium* stage of conidial formation. \times approx. 720.

fungus could readily be placed in that genus. This stage will be referred to in future as the *Cephalosporium* stage. *Cephalosporium* Corda (Icon. Fung. III., II., 1839) is characterized by possessing unbranched conidiophores which arise as short lateral branches which are not swollen at the apex. The hyaline conidia arise singly at the tip of the conidiophore and are pushed to the side by the subsequent conidia without falling off, many holding together in a little mucous, forming a small spherical hyaline head.

As the culture ages, the *Cephalosporium* stage is passed, and conidia are constricted off from side branches which become more and more complexly branched, until eventually large brush-like heads are formed (figs. 4 and 5). The conidia are at first oval to somewhat rounded, but before being cut off from the

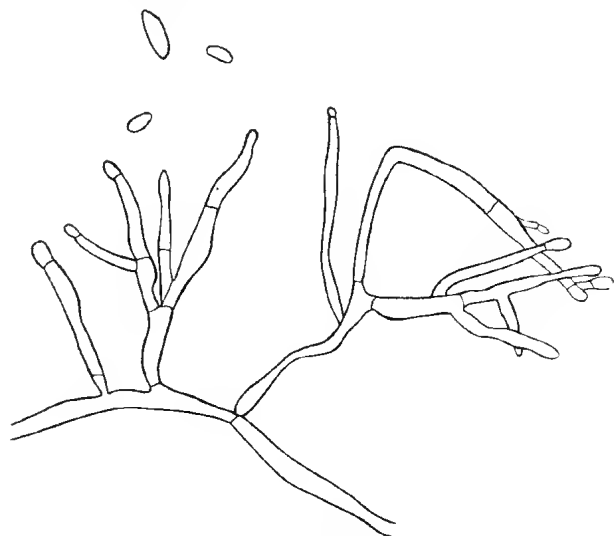


FIG. 4.—Simple branched conidiophores. \times approx. 720.

conidiophore become more pear-shaped or truncate. The branches of the conidiophore are septated and at first hyaline, but on maturing become brown in colour towards the base. The septations of the mature conidiophore are close together and at times give a distinct moniloid appearance. The conidia normally remain hyaline, but very occasionally individual ones may become yellow or brown in colour.

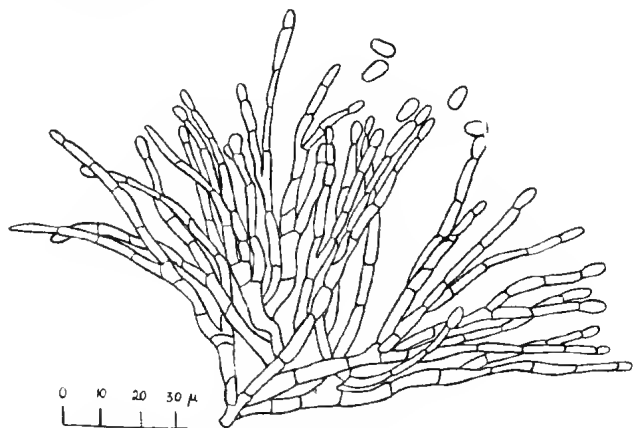


FIG. 5.—Portion of a mature conidiophore. \times approx. 480.

The conidia frequently bud in a yeastlike fashion as soon as they are shed and produce a beaded or monilioid type of mycelium on the surface of the culture, giving rise to the yeasty or sodden appearance mentioned above. At times, this yeast-like budding is so profuse in a young culture, that the surface of the colony is flat and moist and faintly yellow or brown in colour and there is no formation of the long white aerial hyphae typical of most young cultures.

Isolations from the beetle galleries in Mountain Ash, *Eucalyptus regnans*, gave in addition to the typical fungus a much more slowly growing form of *L. Lundbergii*. This form was characterized by a complete lack of aerial mycelium and by the very early formation of typical *Leptographium* conidiophores in sulphur yellow mounds. The first formed conidia were more like the mature conidia in shape and size and not nearly as variable as those formed at first in cultures with more aerial mycelium.

APPEARANCE IN THE BEETLE TUNNELS.

The appearance of the ambrosia fungi in the beetle tunnels in the wood has been described by most authors as a palisade of monilioid chains of cells showing glistening white when young but discolouring with age.

When sections of the tunnels of the Australian ambrosia beetle in myrtle beech are examined under the microscope, a similar condition is seen. If examined closely, however, it will be seen that the palisade consists of fairly wide septated hyphae, which are light-brown at the base and gradually pale off to the tip where a single hyaline, truncate conidium is borne. The septations give the appearance of moniliform chains, but actually only a single conidium is carried at the tip of each septated hypha. This condition is illustrated in Plate IV., figs. 1 and 2, and if the fungal layer is studied and compared with the illustration of Leach *et al* (16) of the ambrosia fungus in the tunnels of the beetle *Trypodendron retusum* in *Populus tremuloides*, the two will be seen to be strikingly similar. At this stage, the ambrosia fungus in the tunnels resembles very closely the apices of the ultimate branches of the mature conidiophores of *Leptographium Lundbergii*. The actual branching of the conidiophores is obscured because of the dense growth of the fungus around the edge of the tunnel.

Since the beetles and larvae are cropping continually at the fungal layer, this complete condition of the apices of the conidiophores with their terminal conidia forming a continuous palisade is not often to be found. More frequently, the short wide hyphae are cut off to about the level of the first septum and are seen with jagged ends while the conidia lie loosely about their bases. An

occasional long septated hypha complete with its terminal conidium projects forth into the cavity of the tunnel where it has been missed by the beetles. At other times less mature conidiophores are seen with narrower hyphae and more rounded conidia at the apex.

The wood adjacent to the tunnels of the beetles is distinctly blackened, giving the appearance that the tunnels have been made by plunging red-hot needles into the wood. The black stain does not spread more than about 1 mm. in a transverse direction or horizontal direction but may extend 10 mm. or more longitudinally from the edge of the tunnel. When sections of the blackened wood are examined, the wood vessels and fibres are seen to be densely packed with dark, much branched hyphae. The presence of these dark hyphae and the resultant staining of the timber around the tunnels lend support to the assumption that the ambrosia fungus is a wood-staining organism. Many yeast-like cells are also present lining the tunnels and at times it is difficult to distinguish between them and the immature conidia of *L. Lundbergii*.

The beetles and larvae keep the fungus closely cropped and the galleries remain clear in their presence. If, however, the timber is kept for a short time after the emergence of the insects, the conidia and yeast cells germinate and give rise to a headed moniloid type of mycelium. This stage is soon passed over and the tunnels rapidly become blocked with a tangle or plug of white mycelium.

COMPARISON WITH OTHER AMBROSIA FUNGI.

Thomas Hartig (11) was the first to recognize the fungal nature of the ambrosia and in 1844 gave the name *Monilia candida* to the ambrosia fungus of the beetle *Xyleborus* (*Bostrychus*) *dispar*.

In 1897, Hubbard (13) discussed the ambrosia beetles of the United States and gave illustrations and descriptions of their respective fungi. Although he made no attempt to name or grow them in culture, he pointed out that they were specific and that only the most closely related species of beetle had the same food fungus. His illustrations are interesting and informative. The long septated conidiophores which he pictured for the ambrosia fungus of the beetle *Xyleborus pubescens* and that of *X. celsus* show a strong resemblance to those described above from the galleries of the Australian beetle, *Platypus subgranosus*. Hubbard observed that an amber brown discolouration tinged the base of the clustered "stems" of the ambrosia of *X. celsus*, but that their terminations were pellucid and filled with colourless protoplasmic granules. This point increases the resemblance to the terminal branches of the conidiophores of *Leptographium Lundbergii*.

He described the ambrosia of *Xyleborus xylographus* as consisting of short erect stems terminating in spherical conidia and pictured the so-called stems each with three or four septa. He stated that the freshly grown fungus is as colourless as crystal but that it is usually more or less stained greenish-yellow, sometimes resembling a coating of sublimed sulphur. Rumbold (19) in a paper on the association of blue-staining fungi with bark beetles in pines, mentioned Hubbard's work on ambrosia beetles and she too noticed the resemblance to *Leptographium Lundbergii*, pointing out that this description of Hubbard's "reminds one of the greenish-yellow clumps of conidia, which later are honey coloured, that characterize the test tube cultures of *Leptographium Lundbergii*, Lagerberg et Melin." The ambrosia fungus of *Xyleborus pubescens* as figured by Hubbard, reminded Rumbold of the conidiophores of either *Ceratostomella pini* or *C. ips*, although she stated that his illustration did not represent them exactly. This point is of interest in view of work to be mentioned later which connects species of *Ceratostomella* including *Ceratostomella penicillata* and *C. ips* with the imperfect stage of *Leptographium Lundbergii*.

Hubbard was of the opinion that the ambrosia fungi were specific and that only the most closely related species of beetle cultivated the same food fungus. However, it is possible that he observed the same species of fungus in different stages and did not recognize the relationship between them.

Schneider-Orelli (22) gave a more complete account of the ambrosia fungus of *Xyleborus dispar*. He stated that the walls of the beetle galleries were lined with hyaline, thin-walled, septated hyphae which swell out at the apex into a sphere; at later stages these spherical cells could be seen in long chains. He mentioned that in the galleries of another species, *Xyleborus saxeseni*, the cells remained single and were not seen in chains. According to Schneider-Orelli, the ambrosia fungus lost its monilial nature when grown in culture and became more truly mycelial. However, even the mycelial growth was characteristic, particularly with regard to the browning of the upper surface of the culture and the reddish-brown and ultimate black colouration of the medium. He did not observe a true spore stage in culture, and on this account did not give the fungus a definite name, not being completely satisfied with *Monilia candida* Hartig.

Three Californian Ambrosia beetles were described by Doane and Gilliland (5) in 1929 and brief references made to the ambrosia fungi associated with them. *Monarthrum scutellare* and *M. detigerum* on oak were found to cultivate a fungus which they thought was probably a species of *Monilia*. They stated that in culture on alfalfa agar "the conidiophores grow from the prostrate mycelium and these bear branching hyphae which form

terminally continuous chains of conidia." As this is the extent of the description of the fungus in culture, it is difficult to compare it with forms examined by other workers.

Trotter (27) in 1934 examined the ambrosia fungus of a tropical *Xyleborus* species in the branches of *Brownea Grandiceps* from Ceylon. He observed a layer of short chains of sub-olivaceous, sterile, torulose, subglobose hyphae, 8-12 μ in diameter, composed of two or more conidium-like segments of which the terminal one was the thickest. A second fungal layer above this consisted of a whitish mass of hyaline, variously shaped continuous conidia ranging from 8 to 4 by 35 to 7.5 μ or even larger. When grown in culture, new conidia were produced of the type observed in nature, and, on the same mycelium, short branches with microconidia. Trotter considered the fungus to belong to an undescribed genus and named it *Ambrosiamyces zeylandicus* n. gen., n. sp. Leach was of the opinion that Trotter was dealing with a fungus completely unrelated to his or Hartig's ambrosia fungus. However, the chains of sub-olivaceous hyphae composed of two or more conidium-shaped segments, crowned by a layer of hyaline conidia are very suggestive of the picture presented by *Leptographium Lundbergii* in the tunnels of the Australian Ambrosia beetle, while the production of micro-conidia on short branches resembles the *Cephalosporium* stage of young cultures mentioned earlier, in which the first formed conidia are frequently very small and are seen in small heads. The possibility that Trotter was dealing with *L. Lundbergii* or a closely allied species does not therefore seem to be excluded.

More recent work on ambrosia fungus has been published by Leach, Hodson, Chilton, and Christensen (16). These authors gave a detailed description of the ambrosia fungus of two species of beetles, *Trypodendron betulae* on birch and *T. retusum* on aspen. These two beetles cultivate the same fungus which Leach and his co-workers considered to show enough resemblance to the ambrosia fungus of *Xyleborus dispar*, as described by Hartig and Schneider-Orelli to be placed in the same genus, though probably in a different species. On account of the confusion over the nomenclature of *Monilia candida*, they made no attempt to apply a new name, thinking that ambrosia fungi should be studied in more detail before their rightful place was decided. Pending further studies, they thought the fungi associated with the beetles *Trypodendron betulae* and *T. retusum* might be considered as strains of *Monilia candida* Hartig.

The ambrosia fungus of these *Trypodendron* species, when grown in culture, was at first hyaline but became brown with age and the medium was discoloured with a diffusible brown stain. At first sporulation was poor and only imperfect monilioid spores, that tended to remain attached and bud in situ, were formed. After repeated subculturing, variants that sporulated abundantly

and consistently were obtained. The spores were hyaline and averaged 11.38μ by 10.09μ in size, with a range of 6 to 17μ in length and 6 to 14μ in width. No reference was made to branched conidiophores, but the description of the fungus otherwise corresponds well with that of *Leptographium Lundbergii*. The authors did not observe the large yellow to brown yeasty patches formed by the typical *L. Lundbergii* conidiophores in culture, but as these are often produced only after a period of two months or more, and sometimes not at all, it is not surprising that their formation was overlooked. The spore measurements come within the range of *L. Lundbergii*. The appearance of the *Trypodendron* ambrosia fungus in the beetle galleries in aspen and that of the Australian beetle, *Platypus subgranosus* in myrtle beech can be seen to be identical, if a comparison is made of the figure in the paper by the above-mentioned workers and Plate IV., figs. 1 and 2 in the present paper.

Verrall (30) made a number of new species for the ambrosia fungi which he found in constant association with species of *Platypus*, *Pterocyclon*, and *Xyleborus*. *Cephalosporium pallidum* is the name which he gave to the ambrosia fungus of the beetle *Xyleborus affinis*. His description of the fungus is as follows:—"On malt agar, colonies are moderately slow growing, reaching 9 to 14 mm. in radius in six days at room temperature. The margins are usually appressed and hyaline while the rest of the colony is covered with a thin layer of hyaline, fluffy aerial mycelium which often becomes appressed with age except for isolated tufts. Aerial mycelium may be entirely lacking. Occasionally a slight brownish tinge develops in parts of old cultures. Yellowish yeasty mounds develop in ageing cultures. In the yeasty mounds, mycelium may be limited to pointed short celled hyphae projecting but shortly from the yeasty mass of conidia and monilioid cells. Compact helicoid hyphal formations were commonly observed in the filamentous mycelium.

Conidia germinate on malt agar by forming monilioid chains of cells which finally give rise to hyphae. Spore heads are formed relatively soon after germination. In culture, typical fruiting consists of cephalosporic heads of conidia protruding but slightly above the agar on erect or decumbent conidiophores. Conidiophores are generally unbranched and hyaline and terminate in one to ten or more hyaline unicellular conidia which are nearly spherical to slightly pear shaped, 7.6μ to 14.4μ long and 7.9μ to 14.0μ wide, averaging 10.8 by 10.4μ . When appreciable aerial mycelium occurs conidiophores elongate and branch. Sometimes the conidiophores are composed partly or totally of moniliform cells, particularly in the yeasty mounds. Occasionally buds were observed forming laterally on hyphae and monilioid chains of spores of irregular sizes and shapes were observed in the agar or protruding above it."

It has already been pointed out that cultures of *L. Lundbergii* pass through a *Cephalosporium* stage when young and that in this condition they might be mistaken for cultures of *Cephalosporium*. Moreover the mature septated conidiophores in the yeasty mounds have a distinctly monilioid appearance and are clustered so thickly together, that unless teased out and examined very closely, their complex branched nature is not readily observed. Altogether Verrall's description of *Cephalosporium pallidum* in culture shows such striking resemblances to *Leptographium Lundbergii*, that the justification for placing it in the genus *Cephalosporium* and his creation of a new species may be seriously questioned. However, his cultures are not available for comparison and it is therefore not possible to say that he was in reality dealing with *L. Lundbergii*. Verrall believed *Cephalosporium pallidum* to be related to *Monilia candida* Hartig. He pointed out, however that Schneider-Orelli, in describing Hartig's fungus, had made no mention of yellowish yeasty mounds or of cephalosporic heads.

Verrall created a second species of *Cephalosporium*, *C. luteum*, for the fungus which he found in association with the ambrosia beetle, *Xyleborus pecanisi*. He did not observe yeasty mounds in cultures of his *C. luteum*, but he reports that the cultures were at first hyaline, though soon becoming sulphur yellow to light-brown, while the agar was stained a deep brown. Aerial mycelium was at first fluffy but became appressed with age. Spores were difficult to find, but when produced formed on simple or branched conidiophores, mostly singly, sometimes in heads of two or three spores. Once again, Verrall's fungus shows marked similarities to *L. Lundbergii*, and once more objection must be raised to his decision to place it in the genus *Cephalosporium*.

The ambrosia fungus associated with the beetles *Pterocyclon mali* and *P. fasciatum* was reported by Verrall to be *Monilia brunnea* n. sp. Cultures of this fungus were at first hyaline but became dark-brown with age and the original isolates were quite yeasty in appearance and consisted largely of monilioid chains of rounded cells that budded in situ. More mycelial growth developed with repeated culturing and small dark-brown mounds of monilial cells were seen in older cultures. These monilial cells were at times distinctly brown in old cultures and borne in simple or branched chains. Verrall expressed the opinion that his *Monilia brunnea* was similar to, but not the same fungus as that described by Leach *et al* (16), for the ambrosia of the beetles *Trypodendron betulae* and *T. retusae* already described above. In spite of the similarities he preferred to create a new species for it. It can be seen, however, that all his points fit into the picture of *Leptographium Lundbergii*, the fungus described in this paper as the ambrosia of *Platypus subgranosus*, and it seems probable that he was in reality dealing with the same fungus.

CONNECTION WITH THE GENUS *MONILIA*.

The striking similarities in the ambrosia fungi described by authors from different parts of the world and discussed above, seem to indicate that they are all closely related or that they actually belong to the same species. In each case, the resemblance to *Leptographium Lundbergii* has been pointed out and the inference to be drawn is that the ambrosia fungus of Hartig, and those of Schneider-Orelli, Leach *et al*, Trotter and Verrall can all be linked up together with the former genus if not all with the species *L. Lundbergii*.

Leptographium Lundbergii is an extremely variable fungus and presents very different appearances at the different stages of its growth. The young cultures in the Cephalosporium stage with their fluffy aerial mycelium might easily be considered to belong to a different genus from the older stages with their appressed light-brown coloured mycelium, darkened agar and typical *Leptographium* conidiophores in the yellow or brown yeasty mounds. Some isolates produce more aerial mycelium and sporulate less frequently than others. It is therefore quite probable that it should have been described under various names by different workers.

The first name given to an ambrosia fungus was that of *Monilia candida*, by Hartig in 1844. However, Schneider-Orelli pointed out that since the work of Hartig, the name *Monilia candida* had been used by Bonorden (3) for a different fungus, the yeast-like form now so well known in the literature of fermentation. Bonorden was apparently ignorant of Hartig's earlier use of the name for the ambrosia fungus. *Monilia candida* Hartig remained completely disregarded for a considerable time, so that any discussion of *Monilia candida* in mycological text books almost always refers to the Bonorden fungus. Although Hartig's fungus actually would have prior claim, the name *Monilia candida* is in such common use for Bonorden's fungus that much confusion would arise in any attempt to change it.

* But in any case, the use of the name *Monilia candida* for the ambrosia fungus seems to be excluded. The genus *Monilia* Persoon is characterized by having conidiophores with dichotomous grape-like or irregular, sparing or frequent branching, bearing at the tips of the branches or on little blunt teeth near the tips the simple or branched chains of hyaline conidia. The conidia of the Australian ambrosia fungus are borne singly, not in chains and therefore it should not be placed in the genus *Monilia*. Provided the assumption is correct that other workers have mistaken the septated terminal branches of the conidiophores of *Leptographium* for monilial chains of conidia, one would be justified in saying that none of the ambrosia fungi should have been placed in the genus *Monilia*.

Relationship of *Leptographium* with the Genus *Ceratostomella*.

Several workers have linked the conidial stage of *Leptographium* with the perfect stage *Ceratostomella*. In 1931, Grosmann (8) described a new species of *Leptographium*, *L. penicillatum* which she found, together with two or three characteristic yeasts, in constant association with the bark beetle *Ips typographus* and sometimes with *Pityogenes chalcographus* in the wood and bark of *Picea excelsa* in Saxon Switzerland and in Württemberg. She distinguished *L. penicillatum* from *L. Lundbergii* by the form and size of its conidia and by the extreme length of its conidiophore. These features seem comparatively insignificant, particularly as the author herself stressed the variability in size of the conidia. Apart from these characteristics, her cultures agreed very closely indeed with the type species, *L. Lundbergii* as to growth and the manner in which the conidia were borne.

She was able to obtain in culture the perfect stage of the fungus which proved to be a new species of *Ceratostomella* and which she described in a later paper (9) under the name of *Ceratostomella penicillatum*. Single spore cultures from ascospores grew well and gave rise to the typical *Leptographium* stage. The ascospores were oval or slightly curved and measured 6.5μ by 2.3μ , while the figures given for the perithecia were diameter of base, 250 to 300μ , length of neck 300 to 500μ , width of neck about 50μ .

Rumbold (19) studied the relation between bark beetles and blue-stain fungi and in a paper published in 1931 discussed two species of *Ceratostomella* which she found in constant association with these beetles. *Ceratostomella pinii* Munch was shown to be constantly associated with *Dendroctonus frontalis* and *D. brevicornis*, and *Ceratostomella ips*, n. sp. with *Ips calligraphus* and *Ips grandicollis*. This new species, *Ceratostomella ips* was described in detail and further points about it given in a later paper (20). Although *Leptographium Lundbergii* was not actually mentioned as the conidial stage, the descriptions and illustrations show a very close resemblance to this fungus. Siemaszko (23) investigating the association of fungi with bark beetles in Poland also assumed that *C. ips* had a conidial stage of *Leptographium Lundbergii*. Describing the formation of the conidia of *C. ips*, Rumbold stated that "those first formed are small, sometimes 2 by 1μ . They are hyaline and obovoid. Later they form on simple conidiophores in a cluster that increases in number as the fungus ages. The conidiophores branch as they grow older until they look like small bushes. In time the bases of the conidiophores turn brown, but the conidia-bearing tips and the conidia themselves remain hyaline. The later conidia range

from 3μ to 10.5 by 1 to 3μ . They are usually clavate." Cultures were at first white but turned warm sepia very rapidly and finally jet black. Perithecia formed in culture were large and long-necked and were 55 to 301μ in diameter with an average of 198μ , 96 to 320μ in height, with an average of 206μ , and the length of the neck varied from 215 to $3,860\mu$, averaging $1,273\mu$. Ascospores had the shape of quadrangular prisms and ranged from 2.9 to 4.6μ by 1.2 to 2.8μ with an average size of 3.8μ by 2μ .

Usually there were no bristles at the ostiole of the perithecium although occasionally a few were seen, irregular both in number and length, measuring from 27μ to 45μ . Rumbold remarked that perithecia were formed in the galleries with their bases sunken in the gallery walls and that the beetles kept the necks well trimmed. After the beetles had emerged, the abandoned galleries were often filled with the protruding bristle-like necks of the perithecia.

Rumbold pointed out that the term "association" as used in the descriptions of the connection between *Ceratostomella pini* and *Dendroctonus*, and between *Ceratostomella ips* and *Ips* does not have the significance of the vital association that exists between the ambrosia beetles and the ambrosia fungi. The association appears to be a more casual one for the bark-boring beetles, which are not known to be dependent on fungi for food.

The conidial stage *Leptographium Lundbergii* was attributed by Rumbold (19) to another species of *Ceratostomella*, *C. piccaperda*, which she found in association with the bark beetle *Dendroctonus piccaperda* on *Picea glauca* in Canada. Perithecia were produced after about five months in culture and the ostioles were without bristles. Ascospores were hyaline and ellipsoid and measured 3.6 to 4.7μ by 1.9 to 2μ with an average of 4.3 by 2μ .

Lagerberg and Melin did not connect their newly-named fungus *Leptographium Lundbergii* with any of the species of *Ceratostomella* but considered it a distinct form. They noted that Falck pictured a fungus exactly similar to it as the conidial stage of *Ceratostomella piceae*, but decided that the author was dealing with a mixture of fungi, *C. piceae* typically has *Cephalosporium* and *Graphium* conidial stages. MacCallum (17) in working with Scottish blue-stain fungi and *Ceratostomella piceae* in particular, also illustrated a branched conidiophore identical with that of *L. Lundbergii*, but he made no mention of it except to note that a mixture of forms was present.

A species of *Ceratostomella* was found by Doane and Gilliland (5) to be associated with the ambrosia beetle *Gnathotrichus sulcatus* on Douglas Fir in California. Two distinct forms, the conidial and perithecial stages, were observed in the galleries.

The conidial stage, which was not given a name and was incompletely described was replaced by definite black perithecia after the beetles had left their galleries. The perithecia were flask shaped and smaller at the base. No further morphological details were given and it is not possible to say which species of *Ceratostomella* the authors were examining.

The Association of *Ceratostomella* with the Australian Ambrosia Fungus.

On examining sections of the tunnels of the Australian ambrosia beetle in the timber of *Nothofagus cunninghami*, a cluster of fine bristles, 35 to 45 μ long was seen occasionally to project into the space of the tunnel from the darkened mass of hyphae filling the wood vessels. In a few cases, these bristles were observed to belong to dark elongated perithecia which had formed in the vessels and which contained small asci with eight hyaline rectangular or prism-shaped ascospores (fig. 6). In addition, groups of ascospores were lying freely in the tunnels adjacent to these perithecia. The ascospores measured 5 to 7 μ by 3 to 4 μ with an average size of 5.9 by 3.5 μ . It should be noted that the measurements only relate to a very small number of ascospores and that an average size for the fungus in question could not fairly be taken from them.

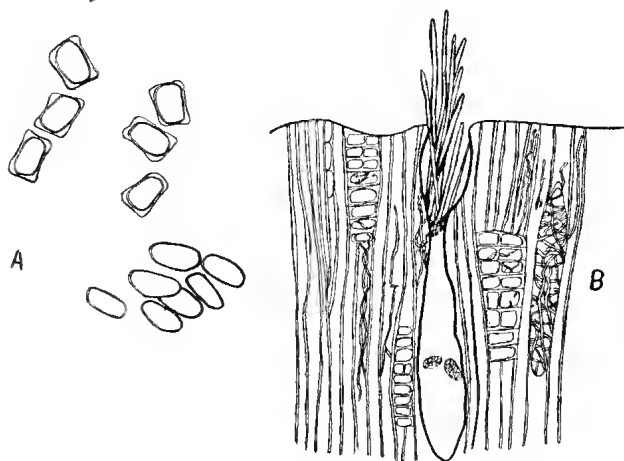


FIG. 6.—A. Ascospores from a beetle tunnel. $\times 960$.
B. Bristles projecting into the tunnel from a sunken perithecium. $\times 160$.

Perithecial measurements could not be made, but the peculiar prism-like shape of the ascospores, the diffuent asci and the presence of bristles associated with sunken perithecia in the tunnels suggest the possibility of an affinity with the species *Ceratostomella Ips* Rumbold. The fact that three species of *Ceratostomella* associated with wood inhabiting beetles have been

described with a conidial stage of *Leptographium*, heightens the probability that the perithecia mentioned above really constitute a stage in the life history of the ambrosia fungus of the Australian *Platypus subgranosus*. Unfortunately all attempts to induce perithecial formation in cultures of *Leptographium Lundbergii* associated with the Australian ambrosia beetles, by the use of strongly acidified media and media rich in carbohydrates have so far been unsuccessful.

Isolation of Yeasts from the Tunnels of *Platypus subgranosus*.

As already noted two characteristic sporogenous yeasts belonging to the genus *Endomycopsis* Dekker were isolated constantly from the beetle tunnels in Australian timbers together with the ambrosia fungus. The two forms have not been placed specifically but have been designated Forms A and B. Stelling-Dekker (26) published a monograph on the sporogenous yeasts and created the genus *Endomycopsis*, placing in it many species which had formerly belonged to the genus *Endomyces*. The genus *Endomycopsis* is characterized by producing a true mycelium with septa together with yeast cells which show many-sided budding. In the genus *Endomyces* she placed those forms with true mycelium and yeast cells which only divide by transverse fission and not by many-sided budding. In both genera, the ascospores are as a rule hat shaped.

In Form A, asci are produced in whorls at the end of much branched septated hyphae and, after the ascospores have been shed, a new ascus is often seen to grow up inside the old one (see fig. 7 and Plate IV.). The asci are oval in shape and range

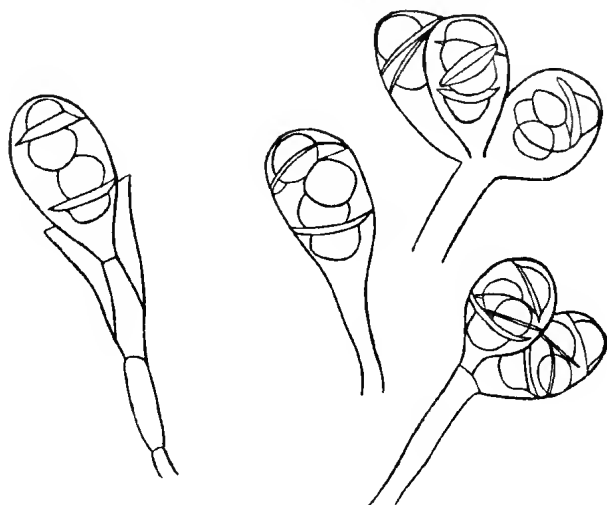


FIG. 7.—Asci and ascospores of *Endomycopsis* sp. Form A.
X approx. 720.

from 17.5 to 26μ by 11.5 to 20.3μ , with an average of 21.5μ by 13.9μ . They contain four ascospores which are large and very striking and which are produced readily on malt agar. They are prominently hat shaped, with the flange forming a definite brim. The measurements are as follows:—

			Range.	Average.
Diameter including brim .. .. .	..	..	$8-14\mu$	11.8μ
Diameter without brim .. .. .	..	..	$5-8\mu$	7μ
Depth .. .. .	..	..	$4-6\mu$	5μ

Only once has a complete ascus of Form A, with its four large hat-shaped ascospores been seen in the tunnel of the Australian ambrosia beetle in Myrtle Beech, although yeast cells have been very often observed.

The asci in Form B are considerably smaller and are more rounded than those of Form A (fig. 8). They may form in chains

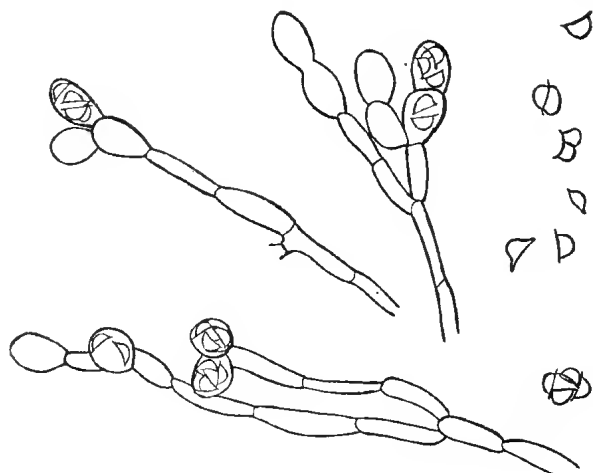


FIG. 8.—Asci and ascospores of *Endomycopsis* sp. Form B.
× 960.

as well as in whorls on the branched septated mycelium. They range from 6 to 9μ by 5 to 6μ averaging 7 by 5.5μ , and they contain four small inconspicuous hat-shaped ascospores. The ascospore measurements are as follows:—

			Range.	Average.
Diameter including brim .. .. .	..	..	$3-5\mu$	3.8μ
Diameter without brim .. .. .	..	..	$2.3-5\mu$	2.9μ
Depth .. .. .	..	..	$1.5-3\mu$	2.2μ

On malt agar, Form A produces a tough, much wrinkled buff-coloured colony with distinctly mycelial edges. In liquid wort, a gelatinous sediment but no pellicle is formed. The colony of Form B on malt agar is white and shining, somewhat wrinkled and fluted in the centre but smooth towards the outside with mycelial edges. With age, the colour becomes greyish. In liquid wort, growth is similar to that of Form A, producing a gelatinous sediment but no pellicle.

The Association of Yeasts with Wood-inhabiting Beetles.

The association of yeasts with wood-inhabiting beetles is of common occurrence and has been reported by many workers.

Schneider-Orelli (22), whose study of the ambrosia fungus of *Xyleborus dispar* has already been mentioned, stated that yeasts were always present in the tunnels of the ambrosia beetles, but he regarded them merely as infections. He did not indicate whether they were always of the same type nor did he give any details.

In 1922, Beck (2), described a new species of yeast, *Endomyces bisporus*, which she found associated with the bark beetle *Ips typographus* on the bark of fir. As the name implies, the ascus only contained two ascospores. Stelling-Dekker transferred this yeast to the new genus *Endomycopsis*, calling it *Endomycopsis bisporus* on the grounds that the yeast cells showed many-sided budding and not just transverse fission. Verrall (3) in 1940 constantly isolated a similar yeast from the tunnels of the ambrosia beetle *Platypus compositus* in pecan, sweet-gum and swamp tupelo, and considered it to be the ambrosia fungus of that beetle. Apparently in ignorance of Beck's earlier work, he called the yeast *Endomyces bispora* n. sp., making no mention of Beck's species of that name or of Dekker's transference of it to the genus *Endomycopsis*.

Siemaszko (23) found members of the Saccharomycetaceae, mostly of a type closely resembling *Endomyces bisporus*, in constant association with *Ophiostoma* (*Ceratostomella*) *penicillata* and other species and the bark beetle *Ips typographus* on spruce in different parts of Poland.

Grosmann (8) in her work on the association of bark beetles and blue-stain fungi also isolated yeasts. They were of three types, a budding yeast with hat-shaped ascospores arising parthenogenetically, a second sporogenous one forming mycelium in addition to yeast cells, and a mycelium-forming asporogenous yeast.

Leach, Orr, and Christensen (15) found a characteristic yeast constantly associated with bark beetles and the blue-staining fungi in felled Norway Pine timber. On examining larvae they were often, although not always, able to demonstrate the presence of yeast cells in the intestine, while they were always present in varying amounts in the food contents of the intestinal tracts of freshly emerged beetles. However, the yeast cells did not show any signs of having been digested and used as food.

Studying the association of bark beetles and *Ceratostomella* spp., Rumbold (20, 21) in 1936 and again in 1941, noted that in making cultures from the timbers around the beetle galleries, yeasts were always the first organisms to appear, the blue-stain fungi only developing later. One of these yeasts was described by Holst (12) in a separate paper as *Zygosaccharomyces pini*, a sporogenous yeast forming hat-shaped ascospores but no mycelium. Holst was unable to produce evidence of any direct relationship between the yeast and the beetle. According to Rumbold, the yeasts seemed to have a stimulating effect on *Ceratostomella montium*, causing it to grow more vigorously and to fruit more quickly than in pure culture.

If, as she suggests, the yeasts tend to accelerate growth and sporulation of the fungus, there may be a definite significance in the constant presence of the *Endomycopsis* spp. in the tunnels of the Australian ambrosia beetles. It is conceivable that they stimulate the growth and fruiting of the ambrosia fungus and so increase the food crop for the beetles and their larvae. In addition to this, being rich in protein, they may serve directly as food for the beetles.

Support for this suggestion is to be found in the work of Guyénot (10) who showed that bacteria-free larvae of the fruit-fly *Drosophila ampelophila* may breed entirely on yeast. Under natural conditions, the larvae feed principally on yeasts and other micro-organisms. He reported that he had been able to raise fourteen generations of the fruit-fly in the absence of living organisms. The larvae were reared equally well on potato and living yeast, potato and dead yeast, and on dead yeast alone, but did not grow normally on sterile potato. These results were corroborated and amplified by Baumberger (1) who found that sterile larvae of *Drosophila* lived only five days and showed no increase in size on agar medium containing sugars, mineral salts, and ammonium tartrate as a source of nitrogen, but grew at a normal rate and pupated normally if the medium were infected with living yeasts. The larvae were also able to live on dead yeasts, showing that they were not dependent on the bi-products of fermentation but actually needed the yeasts as food. A concentration of 2 per cent. yeast was sufficient for normal growth. Baumberger concluded that insects inhabiting fermenting and decaying substrata of low protein content usually feed on the micro-organisms present and thus benefit by the power of fungi to extract, absorb, and synthesize many non-protein compounds.

Steinhaus (25), reviewing work on the microbiology of insects, stated that a type of symbiotic feeding on wood and similar substances is presented by the beetle *Anobium paniceum* which has special appendages of the mid-intestine containing *Saccharomycetes* in their cells.

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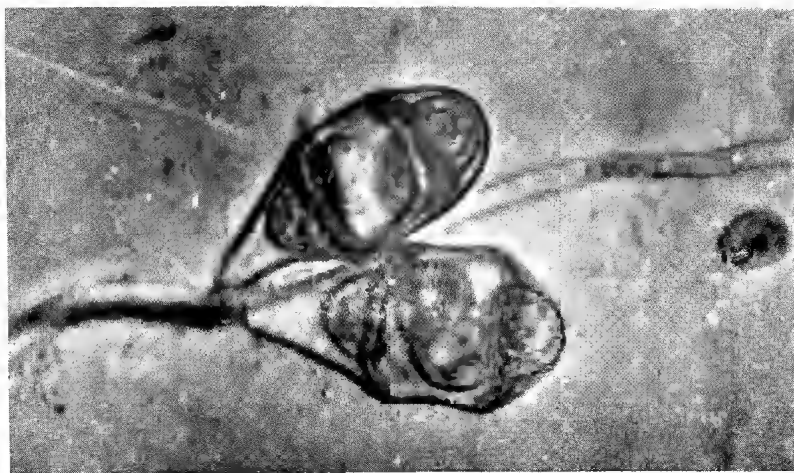
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Description of Plate.

PLATE IV.

- FIG. 1.—Photomicrograph of the fungal palisade lining a beetle tunnel. \times approx. 95.
- FIG. 2.—Portion of the same palisade under a higher magnification, showing ends of the compact conidiophores. \times approx. 400.
- FIG. 3.—Asci and hat-shaped ascospores from a culture of *Endomycopsis* sp. Form A. \times approx. 1,800.



ART. V.—*Botrytis Corm Rot of the Gladiolus—its Cause and Control.*

By G. C. WADE, B.Agr.Sc.

[Read 14th December, 1944; issued separately 10th December, 1945.]

Abstract.

A serious corm rot of the *Gladiolus*, caused by a species of *Botrytis*, probably identical with *Botrytis gladioli* Kleb., is described. The same fungus infects the leaves and flowers of the *Gladiolus*. It overwinters as sclerotes which germinate, producing conidia, under certain conditions. Infected flowers develop abundant conidia. Corms are infected after digging, the fungus entering through the cut stem end or the old corm. It spreads along the vascular bundles and finally causes extensive rotting. The disease may be controlled by dipping with "Hortosan DP," "Zetan," Corrosive sublimate or "Aretan" as soon after digging as possible. The organism has a low optimum and maximum temperature, and the disease may be avoided by digging early. A number of popular varieties are resistant.

Conidia are produced in artificial culture on certain media, under the stimulus of light. The fungus responds to increasing carbohydrate content in the presence of vitamins or plant extracts, but not in their absence. Starch accumulates in actively growing lesions, but in arrested lesions the accumulated starch disappears and a suberised layer develops between the healthy and diseased tissue. The phloem tissue of infected vascular bundles is destroyed before the xylem tissue. Infected corms develop an indicator pigment by reaction between the living corm tissue and the fungus.

Introduction.

In June, 1940, specimens of *Gladiolus* corms, exhibiting a soft rot condition, were forwarded to the Department of Agriculture by a grower at Kalorama, Victoria. The condition did not resemble the *Gladiolus* diseases common in Victoria up till that time, and investigations were commenced to determine its cause and control. As will be demonstrated, in this article, the disease was found to be *Botrytis* Corm Rot.

This disease was first described from Canada in 1927 (5) and has been mentioned in Canadian literature several times since that date (14, 26). Drayton stated that it was common in Holland in 1929 (12), and according to van Poeteren (54) it is gaining ground in that country. Moore (37) first noted the disease in England in 1927. He observed foliage symptoms in Holland in the following year. It was recorded from Long Island, New York, in 1941 (11).

In 1934, Noble *et al* (40) recorded a leaf and stem blight caused by a species of *Botrytis* in New South Wales but, as no mention was made of corm symptoms, this appears to be distinct from the disease described here.

Dimock (10) described an epiphytotic of a leaf and flower blight in Florida which he attributed to a species of *Botrytis*. Tisdale, W. B. (53), has subsequently cast doubt on Dimock's diagnosis and considers the blight was not caused by any organism but by physiologic causes. The lack of corn symptoms and the doubt of the actual cause made it appear a different disease to that described here.

From information obtained from growers the disease was probably present in Victoria for at least a year before specimens were submitted to the Department. It was apparently introduced in imported corms somewhere about 1938-1939. Since the first record from Kalorama it has been recorded from other parts of the Dandenong Ranges, the Geelong district, the Ballarat district, the Mornington Peninsula, and the Metropolitan area of Melbourne. The disease is also present in the coastal regions of New South Wales (correspondence with Drs. C. J. Magee and Lilian Fraser of the New South Wales Department of Agriculture).

Losses caused by the disease have been considerable. Some growers in the Kalorama district have lost over 50 per cent. of the corms of susceptible varieties in years which have been favorable for the occurrence of the disease.

Symptoms of the Disease.

All parts of the plant are affected by the fungus, but from an economic point of view the attack on the corm is the most serious aspect of the disease.

CORM SYMPTOMS.

Corms may exhibit several types of symptoms but, in the opinion of the writer, these symptoms are successive stages in the attack of the fungus on the corm. This view has also been suggested by Moore (37).

In the earliest stage of the disease only the core of the corm is attacked. At this stage there are no obvious external symptoms and affected corms can readily be overlooked in an inspection of corms. A close examination, however, shows a brown discolouration of the basal plate. When the corm is cut the core region shows various stages of a brown rot condition (Plate V., figs. 4-7).

In later stages of the disease the rot travels along the water conducting vessels (Plate V., figs. 5-7) and it is possible for the corm to be extensively rotted internally without obvious external symptoms.

When the disease reaches the surface of the corm, it spreads rapidly producing a soft brown rot. Finally the whole corm may be reduced to a soft, rotten condition. Even at this stage of the disease, the symptoms may not be obvious till the bulb scales are removed. However, an infected corm will feel very soft when squeezed. If the corm is held under humid conditions the fungus produces abundant white, cottony mycelium on the surface of the corm. This mycelium develops large, black sclerotial masses (Plate V., fig. 3). Usually the sclerotes coalesce forming large coralloid bodies. This stage is similar to that illustrated by Hicks (26). The mycelial growth and sclerote development usually occur on the surface of the bulb scales and between the bulb scales and the corm itself.

Under other conditions, which are not completely understood but probably include exposure to light, and to less humid conditions than those which produce the cottony mycelial stage, abundant conidia of *Botrytis* are produced on the surface of the corm. However, this stage is less frequently observed in Victoria than the cottony mycelium-sclerotial stage.

After extended storage the soft, rotten corms gradually dry out to a mummified condition, which usually bears abundant sclerotes on the surface (Plate V., fig. 2).

The extensive internal disorganization of the corm, which in practically all cases involves the entire core region, clearly differentiates this disease from other common *Gladiolus* diseases such as *Sclerotinia* corm rot, *Septoria* corm rot, and *Penicillium* rot. *Sclerotinia* and *Septoria* produce very hard dry rots, which do not usually penetrate very deeply into the corm. *Penicillium* may produce an extensive soft rot, but it can usually be traced to an injury on the surface of the corm and its commencement cannot be traced to the core region. Thus a positive diagnosis of *Botrytis* corm rot can usually be made from a section of an infected corm.

The symptoms of *Fusarium* Yellows (McCulloch, 36) resembles the *Botrytis* disease in several respects. In both diseases the core of the corm is attacked and the disease follows the vascular bundles. This disease has not been recorded in Australia and the author has not had the opportunity of examining specimens, but the presence of sclerotes on *Botrytis* infected corms would distinguish the two diseases. The description in McCulloch's paper suggests that *Botrytis* also causes a softer type of rot than *Fusarium*.

LEAF SYMPTOMS.

The same fungus is capable of attacking the leaves of the plants. Affected leaves usually show a large number of small brown spots, which frequently have a reddish margin (Plate VI.,

fig. 13). The spots may coalesce causing larger brown areas and the leaves may die prematurely. Conidia are produced on infected leaves under field conditions, but much less abundantly than on infected flowers. There is no evidence that this phase of the disease is of great importance under Victorian conditions, as it rarely appears until after flowering, when the plants are already senescent. Until they are senescent *Gladiolus* leaves grow vertically and have a waxy surface. This habit of growth would not favour infection from spores.

FLOWER SYMPTOMS.

Flowers frequently become infected in the field during periods of humid weather. The fungus causes water-soaked areas on the petals (Plate VI., fig. 16). These areas increase in size rapidly and finally cause the flower to collapse (Plate VI., fig. 17). Abundant conidia are produced on infested flowers (Plate VI., fig. 16) and this is important in the life history of this fungus, which does not produce spores readily on most media.

Flowers which are left in the field, thus, contribute a large proportion of the spore load of *Botrytis*.

This attack also causes considerable direct loss, through destruction of blooms.

COLLAR ROT.

The fungus occasionally causes collar rot of the growing plant under Victorian conditions. The foliage of the affected plants becomes yellow and finally the whole plant dies. When the affected plant is pulled up abundant sclerotes can be seen on the collar region of the plant (Plate VI., fig. 15).

This phase of the disease has not proved serious in Victoria, and is usually due to planting infected corms. It is apparently more important under English conditions (37).

The Causal Organism.

ISOLATION.

Numerous cultures from infected corms have been made, using tissue platings on to potato dextrose agar, and a species of *Botrytis* has been isolated consistently from the material.

Isolations have not been readily obtained from infected leaves. Moore (37) experienced the same difficulty. He explained this by suggesting that many of the spots represent abortive infections by *Botrytis*. However, *Botrytis* has been isolated from large leaf spots, formed by the coalescence of several smaller spots.

Isolations have been successfully made from infested flowers, by plating small portions of infected material, which had been surface sterilized with mercuric chloride, on to potato dextrose agar. Isolations have also been made from single spores on the flowers using Ezekiel's (17) modification of Keitt's method (31).

No difference could be detected between the characteristics of the organism isolated from the corms, leaves, and flowers.

MORPHOLOGY.

Mycelium.—The mycelium of the fungus develops abundantly on infected corms held under moist conditions. It is white in colour and is loose and fluffy in texture. Mature hyphae are somewhat variable in size but average 12μ in diameter. Young hyphae are much narrower and average about 4 to 6μ in diameter. The growth on common artificial media is similar to the growth on the host. When grown on potato dextrose agar slopes, the mycelium develops profusely.

Sclerotes.—After several days' growth on the corm, or after about six days' growth on potato dextrose agar, the mycelium near the substrata darkens and sclerotes develop. These are at first creamy in colour but rapidly darken to black. Frequently many sclerotes coalesce forming large coralloid masses. Each individual sclerote is large in size and ranges from 1 mm. to 6 mm. in diameter. The surface of the sclerotes is smooth.

Macroconidia.—Macroconidia are not formed abundantly on artificial media, but develop abundantly on infected flowers, less abundantly on infected leaves and occasionally on infected corms. They are also produced from the sclerotes after several weeks storage under suitable conditions. The conidiophores are brown in colour and of the typical *Botrytis* type (Plate V., fig. 9). The conidiophores are about $12\text{--}14\mu$ in diameter. The cells of the conidiophores are variable in length but average between $170\text{--}290\mu$. This is in marked contrast to the length of the cells of conidiophores of a strain of *Botrytis cinerea* isolated from lettuce. The cells of the conidiophores of the lettuce strain varied from $90\text{--}170\mu$. The macroconidia are ovoid in shape and are $13\text{--}18\mu$ (average 15μ) long and $11\text{--}12\mu$ (average 12μ) wide. They are thus considerably wider than the conidia of *Botrytis gladioli* as described by Klebahn (32), who gives the dimensions of conidia of that species as $8\text{--}15 \times 3\text{--}6$ (average $10.4 \times 4.7\mu$). They agree with the dimensions of conidia from affected gladioli as given by Moore (37), who quotes the dimensions as $12\text{--}15 \times 9\text{--}12\mu$ (average $13 \times 10\mu$), and with the dimensions given by B. O. Dodge and T. Laskaris (11), who give the dimensions as $12.5\text{--}21.4 \times 8.3\text{--}13.2$ (average $15.8 \times 10.5\mu$).

However it is doubtful whether this difference is sufficient to regard this *Botrytis* as a different species to *Botrytis gladioli* Kleb.

Microconidia.—Microconidia were not observed on natural media, but develop freely in the depths of potato dextrose agar cultures over one month old. The sporodochia appear macroscopically as olivaceous green aggregations of hyphae. Microscopically the sporodochia are penicillate. This form is common to many *Botrytis* species (Drayton, 13). The microconidia are produced very abundantly and are spherical and about 2μ in diameter.

No "perfect" stage of the organism has yet been observed, but the development of microconidia suggests that a perfect stage exists. Drayton (13) states that, "it is highly probable that this sexual mechanism is operative, with perhaps slight modifications, in all of the spermatia-producing *Ascomycetes*, including in the term spermatia, microconidia of the type here described."

Groves and Drayton (21) have shown the perfect stage of *Botrytis cinerea* is a *Sclerotinia*.

PHYSIOLOGY.

The organism grows freely on most common media, including potato dextrose agar and malt agar. Its growth on Czapek's solution is not vigorous, unless the solution is supplemented with vitamins. On all these media conidial production is sparse under ordinary conditions. Sclerotes are produced rapidly in cultures on artificial media if the organism has not been subcultured frequently. If, however, the organism is subcultured frequently it eventually ceases to form sclerotes in culture. The mycelium becomes yellowish in colour and a yellow pigment develops in the substratum.

This behaviour resembles the "dual phenomenon" described by H. N. Hansen and W. C. Snyder (23).

In a later note (24) the same authors describe the existence of two forms of *Penicillium notatum*. The C form is the normal conidial type which is maintained in that form if subcultures are made from conidia and care is taken to avoid carrying mycelium over during the transfer. If mycelium is used in subculturing the fungus reverts to the non-sporing M form, which produces a yellow pigment in the substratum.

As *Botrytis* sp. produces conidia sparsely on artificial media subcultures have always been made with mycelium, and this may explain the change in character of the fungus after prolonged subculturing. However, after repeated subculturing for over a year the organisms, although changed in appearance, was found to be still capable of infecting Gladioli.

The influence of a number of factors on the growth of the organism was investigated.

TEMPERATURE.

Methods.—The organism was grown in 200 cc. Erlenmeyer flasks on a liquid medium of potato extract and glucose solution prepared in the same proportions as potato dextrose agar. The solution was inoculated by adding a spore suspension of the organism. The conidia were developed on autoclaved Gladiolus flowers, which were inoculated from a recent isolate on P.D.A. and then exposed to sunlight on the laboratory bench.

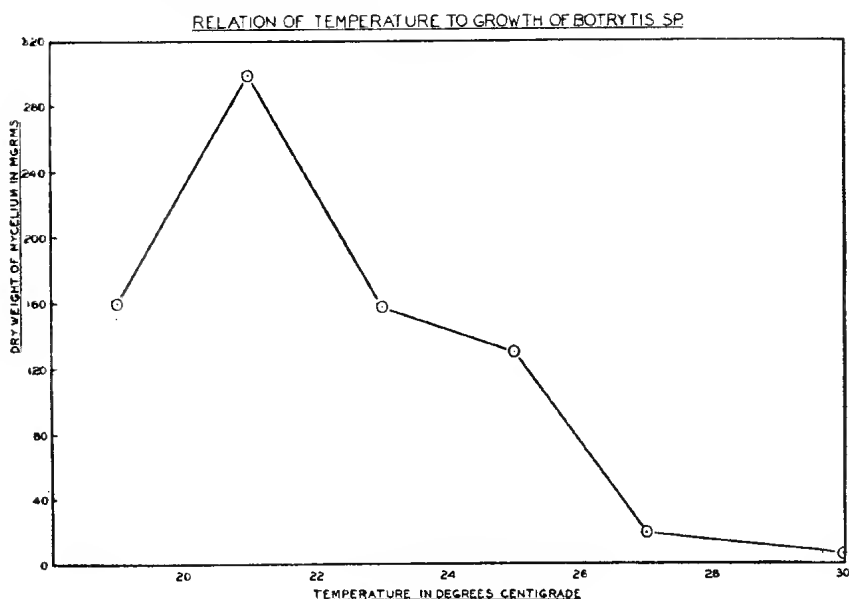
Six flasks were then incubated for ten days at each of the following temperatures:—19°C., 21°C., 23°C., 25°C., 27°C., and 30°C. The fungus mats were then filtered off, washed with hot water, dried at 105°C., and weighed.

Results.—The results are shown in Table I, and are illustrated in Text fig. 1:—

TABLE 1.

—	19° C.	21° C.	23° C.	25° C.	27° C.	30° C.
Weight of mycelium ..	grms. ·160	grms. ·299	grms. ·157	grms. ·130	grms. ·018	grms. ·006

The organism thus has an optimum temperature of about 21°C. and a maximum temperature of about 30°C., which is unusually low for most common fungi.



This low optimal temperature is in agreement with field observations that the disease becomes most serious late in the season when the temperatures are low and the humidity high.

Low temperatures favour other members of this genus. L. E. Hawker (25) has reported that *Botrytis narcissicola* Kleb. causes greater loss of Narcissus at cool or moderate, rather than at higher temperatures.

Brooks and Cooley (3) found that *Botrytis cinerea* had an optimum temperature of about 25°C. The amount of growth fell rapidly as the temperature was raised above the optimum and only slight growth occurred at 30°C.

LIGHT.

Light has been found to stimulate the spore production of many fungi. Hall (22) found that light stimulated the sporulation of *Sclerotinia fructigena* and, when cultures on agar media in petri dishes were left exposed to sunlight on the laboratory bench, alternate zones of vigorously sporing mycelium and sparsely sporing mycelium were produced. The vigorously sporing zones were produced during the daytime and the sparsely sporing zones at night.

G. H. Coons (7) found that pycnidia of *Plenodomus fuscomaculans* were only produced in the presence of light, and C. Ternetz (52) found the asci of *Ascophanus carneus* were produced under the influence of light.

A. Beaumont *et al* (2) found that conidia of *Botrytis tulipae* developed on the host less rapidly in low than high light intensities.

W. Reidemeister (45) found that blue light, but not red light favoured the development of conidia of *Botrytis cinerea*.

Method A.—Cultures of the *Botrytis* on P.D.A. in petri dishes were prepared and when the growth was well established, half the dishes were removed from the incubator and placed on the laboratory bench.

Results.—Some conidia developed on the plates exposed to the light, particularly at the edges of the cultures, while no conidia developed on the unexposed plates in this experiment, and they have only rarely been observed on cultures which have not been exposed to the light. However, sporulation was not vigorous, even on the exposed plates, and therefore light is not the only factor which induces sporulation in the field.

A. Beaumont *et al* (2) produced conidia of *Botrytis tulipae* by exposing P.D.A. plates to light.

Method B.—Wheat grains were soaked over night in water and then 24 test tubes were half filled with the grains, plugged and autoclaved. They were then inoculated with *Botrytis sp.* Twelve

of the tubes were placed on the laboratory bench and twelve in an incubator with a glass front held at 23°C. Half of the tubes on the bench and half of the tubes in the incubator, were wrapped in brown paper to exclude light.

Results.—The tubes were examined after fourteen days incubation and it was found that the cultures exposed to the light on the bench and in the incubator had developed vigorously, and abundant sclerotes had been produced. In both cases the cultures from which light had been excluded, had only developed sparse mycelial growth and very few, small sclerotes. The results are illustrated in Plate VI., figs. 19-22.

Nicolaisen, W., *et al* (39), found that *Sclerotinia trifoliorum* behaves similarly and that darkness retarded both the mycelial and sclerotial development of that fungus.

NUTRITION.

Experiments have been conducted to determine the effect of increased carbohydrate and protein, and the presence of vitamins on the growth of the fungus. In preliminary experiments agar media were used and the diameter of the colonies determined as the criterion of growth. This method is not entirely satisfactory for no allowance is made for the density of the growth of the colony.

Method.—Potato dextrose agar was prepared containing $\frac{1}{2}$ per cent., 1 per cent., 2 per cent., and 4 per cent. of dextrose. To P.D.A. of each of these dextrose contents, 0 per cent., $\frac{1}{2}$ per cent., 1 per cent., and 2 per cent. of peptone were added. Fifteen cc. of the media were then poured into 10 cm. petri dishes and inoculated at the centre with mycelium of *Botrytis sp.* A uniform amount of inoculum was added by using a "biscuit cutter" 1 mm. in diameter as described by Keitt (31). The plates were then incubated at 23°C. in the absence of light. After nine days incubation the plates were examined and the diameter of the colonies determined. The experiment was conducted in quadruplicate.

Results.—The results are set out in Table 2, where the mean colony diameters are quoted:—

TABLE 2.

Peptone Concentration.			Dextrose Concentration.			
			.5 per cent. 5 cm.	1 per cent. 7 cm.	2 per cent. 7.5 cm.	4 per cent. 10 cm.
0 per cent.	..	..		
$\frac{1}{2}$ per cent.	..	..	4 cm.	6.5 cm.	7.0 cm.	10 cm.
1 per cent.	..	..	4 cm.	6.0 cm.	7.5 cm.	10 cm.
2 per cent.	..	..	5 cm.	6.0 cm.	6.5 cm.	10 cm.

The most significant result of this experiment was the marked response to increase of dextrose concentration. A similar response by *Botrytis cinerea* has been found by J. L. Weimer and L. L. Hartner (56). They found that the dry weight of the mycelium increased with increased concentration of dextrose up to 30 per cent. dextrose, and was then reduced by further increase in dextrose concentration.

Peptone had no observable effect on the growth of the organism and apparently *Botrytis* sp. does not require large amounts of protein for growth.

UTILIZATION OF VARIOUS SOURCES OF NITROGEN.

Method.—Czapek's solution was prepared with the usual formula of—

Magnesium sulphate	..	..	..	0.5 grms.
Potassium phosphate (K_2HPO_4)	..	..	..	1.0 grms.
Potassium chloride	..	..	..	0.5 grms.
Sucrose	..	..	..	30.0 grms.
Water	..	..	..	1000.0 ml.

The solution was then divided into six portions. No nitrogen was added to one series and 0.2 per cent. of sodium nitrate was added to another portion, 0.123 per cent. ammonium chloride, 0.163 per cent. of sodium nitrite, 0.156 per cent. of asparagin, and 0.177 per cent. of glycine respectively, were added to the other four portions, the nitrogen added being thus equivalent to 0.2 per cent. of sodium nitrate. 1.7 per cent. of agar was then added to each solution and, after autoclaving, 15 cc. of the various media were poured into sterile petri dishes. They were inoculated as previously described and then incubated at 23°C. for six days, when they were examined and the diameter of the colonies determined. There were four replicates of each treatment.

Results.—The results are shown in Table 3:—

TABLE 3.

Nitrogen Source.					Colony Diameter.	Type of Growth.
					cm.	
Nitrogen free	..	..	..	..	10	Extremely sparse growth
Sodium nitrate	..	..	..	..	10	Normal growth
Ammonium chloride	..	..	..	..	8	Normal growth
Sodium nitrite	..	..	..	..	4	Flat yellowish growth
Asparagin	..	..	..	..	7	Normal growth
Glycine	..	..	..	..	7	Normal growth

These results indicated that sodium nitrate was the most suitable source of nitrogen for *Botrytis* sp. S. J. Du Plessis (15) in experiments on the physiology of *Botrytis cinerea*, found that the greatest weight of mycelium per unit of nitrogen consumed was on a nitrate containing media.

Therefore sodium nitrate has been used as the nitrogen source in subsequent experiments.

These results demonstrate the unsatisfactory nature of colony diameter as a criterion, since the diameter of the colonies on media with no nitrogen was greater than when ammonium chloride, sodium nitrite, asparagin, or glycine were present, but actually the growth was extremely sparse and the weight of the colony would have been very much less than the weight of the colonies on any of the other media,

UTILIZATION OF CARBOHYDRATE IN A SYNTHETIC MEDIUM.

Method.—Czapek's solution plus agar, containing 1.5 per cent., 3 per cent., 6 per cent., and 12 per cent. of sucrose was prepared. The same technique as has been already described was used and the colonies were measured after six days' incubation.

Results.—The results are shown in Table 4:—

TABLE 4.

Sucrose Concentration.				Diameter of Colony.
%				cm.
1.5	..	..	..	3.0
3.0	..	..	..	2.5
6.0	..	..	..	3.0
12.0	..	..	..	4.0

Thus the fungus did not respond to increased sucrose concentration. It was therefore obvious that potato extract contained some growth factor not present in the synthetic medium, and without this factor the fungus did not respond to an increase in carbohydrate.

EFFECT OF VITAMINS ON THE GROWTH OF THE FUNGUS.

In 1858 Pasteur (43) had shown that growth of lactic acid bacteria was stimulated by the addition of onion juice to the medium. In 1860 Pasteur (44) found that the development of yeast in a synthetic medium was markedly improved by the addition of organic substances present in natural materials. These observations of Pasteur were the first indication of the existence of growth factors.

The importance of vitamins for the growth of certain fungi was first demonstrated by Schopfer (47) in 1934. He found that *Phycomyces Blakesleeanus* required thiamin for growth.

Schopfer (48) lists the following ascomycetes requiring thiamin for growth:—*Saccharomyces cerevisiae*, *Nematospora gossypii*, *Nectria coccinea*, *Sphaerula trifolii*, *Valsa pini*, *Helvella*

infula, and *Haplodermium pinestri*. The importance of thiamin for these organisms was demonstrated by a number of workers, who are quoted by Schopfer.

The importance of pantothenic acid was found by Williams *et al* in 1933 (58), and nicotinic acid was shown to be essential for the growth of *Staphylococcus aureus* by Knight (33) in 1935.

Biotin was extracted from egg yolk by Kögl and Tönnis (34) in 1936 and found to be still active on *Saccharomyces* at a dilution of 1 in 4×10^6 .

In 1939 Orla-Jensen *et al* (41) showed that lactic acid bacteria required riboflavin for growth.

A full account of the historical development of this subject is given by Schopfer (48).

In view of the known importance of vitamins to fungal growth, an experiment was conducted to determine whether a mixture vitamins of the B complex, either with or without biotin, would supply the factor, without which *Botrytis* did not respond to increasing dextrose concentration.

Methods.—Czapek's solution, with the addition of 0.5 grams of calcium chloride, but without sucrose was used as the base solution. Heavy metals (iron, copper, manganese, and zinc) were added to the base solution. Solutions containing 0.5 per cent., 1 per cent., and 2 per cent. of dextrose were prepared.

Ten per cent. by volume of potato extract, prepared by boiling 20 grams of potato in 100 ml. of water and filtering, was added to one series.

Members of the B complex of vitamins (thiamin, riboflavin, nicotinic acid, calcium pantothenate, and pyridoxin) were added to another series to give final concentrations of 1 γ per 50 ml.

These vitamins, together with biotin concentrate to give a final concentration of 1 γ per 50 ml. were added to another series. No addition was made to a fourth series of solutions.

Forty-eight ml. of the various solutions were pipetted into 200 ml. Erlenmeyer flasks and autoclaved at half an atmosphere for twenty minutes.

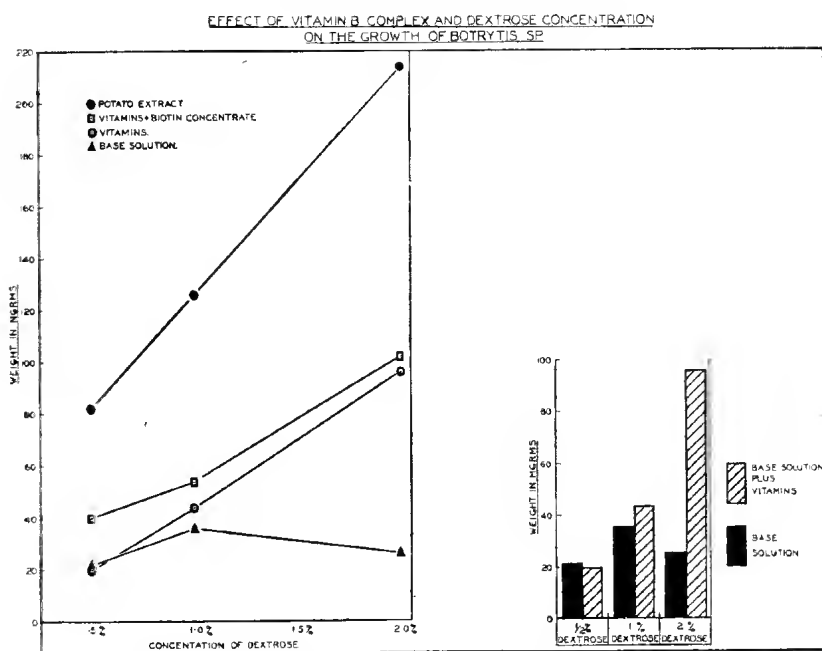
They were then inoculated by adding 2 ml. of a spore suspension of *Botrytis* with a sterile pipette. The spore suspension was prepared from a culture on autoclaved gladiolus flowers. To reduce the risk of carrying over vitamins from the flowers, the spores were washed twice by centrifuging, syphoning off the supernatant liquid with sterile capillary tubing, and adding fresh distilled water.

The flasks were then incubated at 25°C. for ten days, when the mycelium was filtered off, washed with boiling water, dried at 105°C., and weighed.

Results.—The results are shown in Table 5 and are presented graphically in fig. 2:—

TABLE 5.

Dextrose Concentration.			
Addition to base solution	% $\frac{1}{2}$	% 1	% 2
No addition	·022	·036	·26
B. complex vitamins	·020	·044	·096
B. complex vitamins plus biotin conc.	·040	·054	·102
Potato extract	·082	·126	·214



The following statistical report on the results has been prepared by Dr. H. C. Forster of the Victorian Department of Agriculture:—

“A statistical analysis of the results has been conducted to determine (a) the significance of the difference between the respective treatments, (b) the significance of the difference, if any, between the regression coefficients of the three treatments which included vitamins.

Since the variation shown by the replicates of the different treatments varies directly with the mean value of the treatment, the analysis has been conducted not on the original figures but on a transformation based on $\log (100 x)$.

COMPARISON OF THE DIFFERENT TREATMENTS.—RESULTS ON BASIS OF $\log (100 x)$.

Base Soln.			Base + VB.			Base + VB + biotin.			Base + Potato Extract.		
½%	1%	2%	½%	1%	2%	½%	1%	2%	½%	1%	2%
·34	·54	·40	·30	·64	·98	·60	·68	1·08	·92	1·10	1·34
·43			·64			·79			1·20		

S.E. (between dosages) = ·054 For significance, differences must exceed ·15.

S.E. (between treatments) = ·033 For significance, differences must exceed ·09.

F 1% both between main treatments and within main treatments.

It is evident therefore that there are significant differences both between the various main treatments, and except in the case of the base solution, between the dosages of those treatments.

COMPARISON OF REGRESSION COEFFICIENTS OF DOSAGE
REGRESSION LINES OF THE VARIOUS TREATMENTS.

It is obvious that the regression line of the base solution is significantly different from the other three regression lines. The base solution treatment has therefore been deleted from this analysis and a test conducted to see whether the other three regression lines differed one from the other.

Analysis. Treatment d/f.	<i>x</i> .	<i>y</i> .	<i>xy</i> .	$\frac{\sum xy}{\sum x^2}$	Errors of Estimate.		
					$y - \frac{(\sum xy)^2}{\sum x^2}$	d/f.	M.S.
Base + VB 2 ..	·90	1·156	1·020	1·133	0·004	1	0·032
Base + VB + biotin 2 ..	·90	·662	0·720	0·800	0·086	1	
Base + Potato Extract 2 ..	·90	·448	0·630	0·700	0·007	1	
Total ..	2·70	2·266	2·370	0·878	0·185	5	0·037

$F = \frac{·037}{·032}$ which is not significant.

It is apparent therefore that there is no significant difference between the regression coefficients of these three treatments.

It should be noted that the regression coefficients of the above table are those of the transformed figures. (References—Snedecor (51) and Cochran (6).)

The results demonstrate that there is no response to increasing dextrose concentration when no vitamins and a purely synthetic medium is used. When vitamins are added to the base solution however, a marked response is obtained. There was no significant difference between the gradients of the curves for increasing dextrose content when vitamins and biotin, or potato extract are added to the base solution. This suggests that vitamins are the main limiting factor in preventing response to increased dextrose. The greater growth obtained with potato extract could be explained by the additional carbohydrate added with the extract and an extra growth factor is not necessarily present.

Schopfer (48) in commenting on results obtained by Leonian and Lilly, suggests that the effect of organic acids (succinic and fumaric) on the response of *Phycomyces* to thiamin is due to the addition of nutrients (carbon compounds and minerals) rather than to an additional growth factor. In this case the response could not be due to minerals, since pure mineral salts were not used and all the elements known to be important in fungal nutrition were added to all solutions.

Little response to vitamins was obtained at low dextrose concentrations, but a very marked response when 2 per cent. was present (see fig. 2). Burkholder and McVeigh (4) found that with 4.0 and 8.0 grams per litre of asparagin and thiamin at 1×10^{-6} Molar, glucose was limiting up to quantities of 80 or 100 grams per litre.

A definite response to biotin concentrate was obtained. Crystalline biotin was not available for the experiment and unpublished data by Millikan suggests that the biotin concentrate used contains growth factors other than biotin.

It is unlikely that all the vitamins added are essential for the fungus and further work will be conducted to elucidate this point.

PRODUCTION OF CONIDIA.

In the field, conidia are produced abundantly on infected flowers, less abundantly on infected leaves and occasionally on infected corms, but, as already stated in previous sections, conidia are not produced readily on ordinary media.

Newton (38) found that conidia of *Botrytis tulipae* were produced when the fungus was grown on tulip extract agar, although this fungus does not produce conidia on barley meal, corn meal, or synthetic agar media. Gladiolus dextrose agar was prepared in the same manner as potato dextrose agar. However, when the fungus was grown on this medium, in the absence of light, in an incubator at 23°C., no conidia were produced. When grown on this medium in the presence of light on the laboratory bench some conidia were produced, but not more than on potato dextrose agar under the same conditions.

As conidia are produced on naturally infected flowers, gladiolus flowers were placed in Erlenmeyer flasks and autoclaved. They were then inoculated with *Botrytis* sp. and placed in an incubator at 23°C. They were then transferred to a laboratory bench exposed to the light. In 21 days after the start of the experiment, conidia had developed abundantly on the flowers.

Hopkins (28) noted the vigorous sporulation of *Botrytis tulipae* on infected flowers and suggested this was due to the favorable moisture relations. He therefore grew *Botrytis tulipae* on potato dextrose agar in petri dishes and allowed the medium to dry out and conidia were produced on these plates.

Reidemeister (45) considered that the drying out of cultures, or culturing on media of high osmotic pressure, were the most important factors in inducing sporulation of *Botrytis cinerea*.

An experiment was conducted to determine whether drying out of the medium or exhaustion of the food supply would induce sporulation of *Botrytis* sp.

Method.—One millilitre of potato dextrose agar was pipetted into each of twelve 200 ml. Erlenmeyer flasks, autoclaved and inoculated with *Botrytis*. They were then incubated at 23°C. for seven days. The plugs of six flasks were then dipped into paraffin to prevent the drying out of the agar. The remainder were unwaxed. Three waxed and three unwaxed flasks were then placed on the laboratory bench, where they were exposed to light, and the same number of waxed and unwaxed flasks left in the incubator away from light.

Results.—After fourteen days it was found that conidia had developed on both sets of flasks which were exposed to light, but no conidia had developed on either set kept away from light.

A similar experiment was also conducted with gladiolus flowers, gladiolus stems and cyclamen flowers, and again it was found that conidia were produced on the materials in both waxed and unwaxed flasks, which were exposed to light, but not in the flasks kept away from light.

These results indicate that both exhaustion of the food supply and drying out of the medium can induce sporulation provided the cultures are grown in the presence of light.

The effect of impoverishment of food supply on sporulation has been observed with many fungi. For example, G. H. Coons (7) found that rapid fruiting of *Plenodomus fuscomaculans* could be induced by removing a strongly growing culture to a dilute nutrient solution, or to distilled water. It appears that factors which are unfavorable to continued vegetative growth, are favorable to sporulation.

It has been noted that, after preparing a spore suspension from spore-bearing flowers in Erlenmeyer flasks, sporulation is profuse. This may be due to washing away nutrients when the suspension is prepared.

Apart from sporulation which develops from the mycelium under the conditions described, conidia are produced from sclerotes on cultures on any common medium, after the cultures are several months old. Plate V., fig. 11, shows conidial production from a sclerote from a potato dextrose agar culture. Conidial production has been observed from sclerotes in cultures which had been stored away from light, but conidial production occurs more rapidly in cultures exposed to light.

Botrytis cinerea produces conidia from sclerotes in a similar manner (60).

Effect of the Fungus on the Corm.

HISTOLOGY.

Sections were cut of corms in which the disease was active and of corms in which the disease had been arrested. The usual method of paraffin embedding was used, except that 5 per cent. of microcrystalline wax was incorporated in hard paraffin to prevent the paraffin forming large crystals and thus facilitate sectioning.

In active lesions the middle lamella of the cells of diseased parenchymatous tissue had been destroyed and the cells greatly distorted. The cell contents showed no definite structure but contained an accumulation of starch granules. At the edge of diseased lesions there is usually a sharp line of demarkation between the almost completely disorganized diseased tissue and the surrounding normal tissue (Plate VII., fig. 23). The mycelium of the fungus was abundant in the disorganized tissue and sometimes penetrated to a depth of several cells into apparently normal tissue.

In some sections, however, there was a layer of cells containing a reduced number of starch grains, between the infected tissue and the normal tissue (Plate VII., fig. 24). The infected tissue contained an accumulation of starch granules and there was no suberimised layer at the edge of the healthy tissue. It therefore differed from the histological structure of arrested lesions, which will be described later.

As previously stated the disease travels along the vascular bundles. The phloem tissue of the infected bundles is rapidly disintegrated and later the wood vessels are attacked and destroyed. Plate VII., figs. 26*a* and *b* shows a longitudinal section through an infected vascular bundle. The phloem tissue has been

almost completely destroyed but the wood vessels still show fairly normal structure. Hopkins (28) noted that *Botrytis tulipae* destroyed the xylem of infected tulips.

Infected tissue of corms, in which the disease has been arrested differ in several respects from those just described. The severely infected tissue is similar to that in actively growing lesions but no starch granules are present. It is surrounded by a layer of cells about 1 to 2 mm. wide, which have practically no cell contents and very few starch grains, but the cell walls do not show marked distortion. This layer of cells only contains few hyphae of the organism. At the edge of these cells there is a layer of rectangular suberised cells and beyond that the tissue is normal (Plate VII., fig. 25).

The development of a suberised layer around diseased lesions in tubers and corms has frequently been reported. Hill and Orton (27) found that potato tubers infected with bluestem disease produce a layer of suberised tissue around the infected tissue.

MICROCHEMICAL TESTS.

To determine the chemical changes in the diseased tissue a series of microchemical tests were conducted. Fresh, hand sections were used, and methods described by Johansen (30) and by Hill and Orton (27) were employed for most of the tests.

METHODS AND REAGENTS USED.

STARCH AND DEXTRIN.

The usual iodine test.

SUBERIN.

A solution of Sudan III. in 95% alcohol.

REDUCING SUGARS.

The osazone test as described by Johansen.

PROTEINS.

The sections were stained for 24 hours in a saturated aqueous solution of picric acid.

CELLULOSE.

They were placed in a drop of iodine solution and a drop of 75% sulphuric acid was allowed to diffuse under the coverslip.

METHYL PENTOSSES.

The sections were placed in one or two drops of acetone, a drop of hydrochloric acid was added and the sections warmed for fifteen minutes.

LIGNIN.

The sections were placed in a 1% alcoholic solution of phloroglucinol and a drop of hydrochloric acid added.

ARABAN AND XYLAN.

The test was conducted as for lignin but the sections were warmed for ten minutes.

PECTIN.

The sections were stained in a dilute aqueous solution of ruthenium red.

TANNINS.

The sections were placed in 10% aqueous ferric chloride plus a little sodium carbonate.

SAPONINS.

The sections were placed in concentrated sulphuric acid.

RESINS.

The sections were left in a 7% aqueous solution of copper acetate for 5 days.

OXIDASE.

The sections were placed in a 1% solution of benzidine in 60% alcohol.

PEROXIDASE.

The sections were placed in a 1% solution of benzidine in 60% alcohol and a drop of hydrogen peroxide added.

CATALASE.

The sections were placed in a 1% solution of gum arabic and a drop of hydrogen peroxide was added.

NITRATES.

The sections were placed in a 0.1% solution of diphenylamine in 75% sulphuric acid.

PHOSPHATES.

The method used was that employed by Humphrey and Dufrenoy (29). The sections were placed in a mixture of 5 ml. of a solution of 20.8 ml. of sulphuric acid, and 6.41 grms. of ammonium molybdate made up to 250 ml. with distilled water; and 1 ml. of a solution of 0.5 grms. of 1-amino-2-naphthol-4-sulphonic acid and 5.75 grms. of sodium-bisulphite, plus 5 ml. of a 20% solution of sodium sulphite made up to 90 ml. with distilled water.

CALCIUM.

The sections were placed in a 2% aqueous solution of oxalic acid. The acid was withdrawn after thirty minutes, a coverslip added and alcohol allowed to diffuse under the coverslip.

CALCIUM OXALATE.

The sections were placed in a 7% aqueous solution of copper acetate.

SULPHATES.

The sections were placed in a 1% solution of benzidine chloride in 3% hydrochloric acid.

Results.—The parenchymatous tissues of healthy gladiolus corms contain starch grains, but they are not present in the tissue of the vascular bundles. In corms in which the disease is active,

excessive accumulation of starch occurs in the infected tissue (Plate VII., figs. 23 and 24). The surrounding healthy cells do not show any marked reduction in the number of starch grains present. Hopkins (28) noted that starch accumulated in tulip bulb tissue infected with *Botrytis tulipae*.

Pectin is absent from the diseased areas but is present as the middle lamella in healthy tissue. The capacity of *Botrytis* species to utilize pectin has been noted by several workers. A report by the Food and Vegetables Committee, Department of Science and Industrial Research (9) states that in studies of the parasitism of *Botrytis* sp. on the apple it was found that the organism utilized considerable quantities of pectin. Davidson and Willaman (8) reported that *Botrytis cinerea* produces pectinase. The capacity of *Botrytis* to utilize pectin explains the rapid disorganization of infected tissue.

The cell walls are changed to a material which stains yellow with iodine and is apparently a dextrin.

No reducing sugars were detected in healthy tissue, but glucosozones developed in some sections of diseased tissue which were tested. The osozones did not appear till after forty-eight hours, which suggests the reducing sugar present was glucose.

Saponins and the enzymes catalase and peroxidase were present in both healthy and diseased tissue. Oxidase was not detected in diseased tissue and it was only detected in developing shoots of the healthy tissue.

Free nitrates, lignin, methyl pentoses, resins, tannins, calcium, calcium oxalate, and sulphates were not detected in either healthy or diseased tissue. Suberin was not detected in, or at the edge of, active diseased lesions. The phosphate test was not conducted on material of this type. No deposits of protein material were detected in healthy or diseased tissue.

A pigment, which changes to vinaceous-rufous—Ridgeway's colour chart (46)—on the addition of alkali is produced in infected tissue. This pigment is water soluble and, when extracted from the corn, is amber yellow coloured. It changes to vinaceous-rufous at pH 6.8 and may be precipitated from aqueous solution by the addition of excess acid. The chemical nature of this material has not been determined.

Small quantities of the same pigment are produced in gladiolus corns infected with *Septoria gladioli* or *Bacterium marginatum*.

The pigment is not produced by *Botrytis* when the organism grows on potato dextrose agar or gladiolus dextrose agar. *Botrytis* was grown on autoclaved gladiolus corns, but no

indicator pigment was produced. Therefore the pigment is produced by living gladiolus corm tissue when invaded by *Botrytis*, *Septoria gladioli*, or *Bacterium marginatum*.

Kreuzer (35) found that a pigment which changes in colour from red at pH 8.5 to yellow brown at pH 4.5, is produced in onion roots infected with *Phoma terrestris*.

The chemistry of infected tissue in corms in which the disease has been arrested differs in several features from infected tissue of corms in which the disease is active. The disorganized tissue contains little or no starch but is similar in other respects to that described previously.

The phosphate test demonstrated the presence of free phosphate, or loosely combined phosphorous compounds, in the healthy tissue, but no reaction for phosphates was obtained in diseased tissue. Humphrey and Dufrenoy (29) found that free phosphate appears in oat tissue infected with crown rust. Apparently in the case of *Botrytis* the phosphates are used by the fungus and do not accumulate. This tissue is surrounded by a layer of cells, about 1 to 2 millimetres wide, which is practically devoid of cell contents. The cell walls are not distorted in shape but stain yellow with iodine showing that they have been partially broken down to dextrans. The middle lamella stains progressively fainter with ruthenium red towards the disorganized tissue, indicating that it has been partly dissolved.

This layer is surrounded by rectangular cells, with suberised walls, and beyond the tissue is normal (Plate VII., fig. 25).

Pathogenicity and Host Range.

The pathogenicity of *Botrytis* to gladioli was demonstrated by inoculating healthy corms, with a pure culture of the organism. The organism was introduced by needle puncture, and the corms were then placed in jars containing a free water surface. After several days brown lesions, typical of the disease in the field, developed (Plate V., fig. 12) and they increased rapidly in size with continued incubation.

Isolates were made from the edges of lesions on artificially infected corms, and *Botrytis* was consistently isolated.

The disease has only been observed under field conditions on varieties of *Gladiolus primulinus* and gladiolus hybrids.

Limited infection experiments, using the technique described above, were conducted on corms or bulbs of cyclamen, narcissus, *Gladiolus colvillii*, and *Ixia grandiflora*. Infection occurred in corms of *Gladiolus colvillii* and *Ixia grandiflora*, though the disease has not been observed on these plants in nature.

Method of Infection in the Field.

It has previously been stated that *Botrytis* enters the gladiolus corm along the vascular bundles. Large numbers of infected corms were examined and in all cases at least portion of the core of the corm was infected and had spread from the core to other portions of the corm along the vascular bundles. In no case had the fungus entered the corms through parenchymatous tissue.

From theoretical considerations the fungus could enter the core of the corm through the old corm from infected soil, it could pass down into the corm from infected foliage or it could enter the corm by infection of the cut stem, or the old corm, after the corms were dug.

In most of the infected corms examined the whole of the core was diseased. In some corms, however, only the top portion of the core was infected. In these cases infection could have occurred by the fungus passing down into the corms from infected leaves or by infection of the cut stem end while the corms were on the drying racks (Plate V., fig. 8). A few corms only showed infection of the lower portion of the core. Infection could have occurred from infected soil or by infection of the corms on the drying racks.

Pot experiments were conducted in 1941-42 in order to determine the probable method of infection in the field.

The susceptible variety, Picardy, was used for the experiment and the plants were grown in virgin, red mountain soil in 8-in. pots. One series was planted into soil which was inoculated by mixing it with infected corm material. The leaves of another series were inoculated, before the plants flowered, by brushing them with conidia developed on artificially infected flowers. Another two series were inoculated in the same way immediately after flowering. After inoculation the plants were held in a humidity chamber for twenty-four hours and then removed to the glass-house.

Abundant lesions, typical of *Botrytis* infection in the field, developed on all the inoculated leaves.

The corms were dug six weeks after flowering and the pre-flowering inoculated series, one of the post-flowering inoculated series and the soil inoculated series were stored in closed tins to reduce the rate of drying of the corms. The other post-flowering inoculated series was stored under good conditions on a wire-netting stretcher.

The freshly cut stem ends of two other series were inoculated by brushing with dry conidia of *Botrytis*. One series was stored in a closed tin and the other on a wire-netting stretcher.

Two other series were not inoculated and one stored in a closed tin and the other on a wire-netting stretcher.

There were six replicates in each series throughout the whole experiment.

After storage for eight weeks the corms were examined and it was found that typical *Botrytis* rot had developed in the series in which the cut ends of the corms were inoculated at digging time and then stored in closed tins. The corms in all the other series did not develop the disease.

This experiment demonstrated that infection can occur through the cut stem ends of the corms, if they are stored under humid conditions. The experimental conditions may not have been favorable for soil infection as the pots were well drained, and soil infection may require a high soil moisture content. However, evidence in the field does not suggest soil infection is important, and serious infection of corms, which were grown on virgin soil, has been observed. The failure of soil sterilization experiments to control the disease supports this view.

As heavy leaf infection was obtained in the experiment, it is unlikely that infection of corms develops by the disease passing down from the leaves into the corms. This view is supported by the failure of foliage sprays to control the disease, and evidence from the control experiments conducted subsequent to this experiment suggests that all field infection occurs on the drying racks after digging.

As some of the infection on the racks could occur through the cut stem end of the corm and some through the old corm it seemed possible that the amount of infection would be reduced if the tops were not removed from the corms after digging.

Therefore an experiment was conducted in the 1943-44 season in which 200 corms of Picardy were dug and stored, without removing the tops, on wire-netting stretchers. The tops were removed from an equal number of Picardy corms and they were stored under the same conditions.

The corms were examined after ten weeks' storage and it was found that 45 per cent. of the corms from which the tops had been removed were infected, while only 34 per cent. of the other series were infected. Thus the disease enters both from the cut stem end and through the old corm.

Control.

Control measures recommended by Dodge and Laskaris (11) and Moore (37) are stringent field and storehouse sanitation. These methods would probably reduce the disease but are not a completely satisfactory solution to the problem.

The experiments on control described here were designed to prevent the entry of the fungus into the corms. As the disease attacks the interior of the corm it is obvious that dipping infected corms with fungicidal solutions will not control the disease. A limited number of experiments were carried out in an attempt to sterilize infected corms by volatile materials, and these will be described later, but the method was not successful.

Because of the three possible methods of entry described in the preceding section, experiments were conducted on soil sterilization, spraying to prevent foliage infection and dipping of the corms at digging time.

Experiments were also conducted on the influence of time of digging and to determine whether any varieties of the gladiolus were resistant to the disease.

SOIL STERILIZATION EXPERIMENTS.

An experiment on the effect of soil sterilization was conducted in the 1940-41 season.

Method.—Trenches 4 inches deep and 40 feet long were dug, and the fungicidal materials were then applied. The soil was then replaced and the treated areas covered with bags for five days. After fourteen days 100 corms of the variety Picardy were planted in each treated row and an untreated row. The experiment was laid out as a randomized block and there were four replicates of each treatment.

The treatments tested were—formalin, 2 per cent. applied at the rate of $\frac{1}{2}$ gallon per square yard, bleaching powder at the rate of 1 lb. per 20 square yards and carbon bisulphide at the rate of 1 pint per square yard.

Six weeks after the plants had flowered they were dug and placed on wire-netting stretches in the same order as their position in the field. After storage for six weeks the scales were removed from the corms and the number infected with *Botrytis* were determined.

Results.—The plants grew normally, except that the foliage of the carbon bisulphide treated rows was deeper coloured than the controls during the early stages of growth, though the effect was not maintained throughout the season. This was apparently due to partial soil sterilization (Waksman, 55).

TABLE 6.

			Control.	Formalin.	Bleaching Powder.	Carbon Bi-sulphide.
Percentage	..	..	29·6%	39·3%	26·3%	25·2%
Angle	..	..	32·94°	38·77°	30·86°	30·07°

Determination of the F value (Snedecor, 50) showed that the differences in the experiment were not significant. The method of angular transformation is taken from Cochran's paper (6).

Soil sterilization does not therefore appear to offer any possibility of control, and this experiment, considered together with evidence previously presented, indicates that soil infection is not an important factor in the disease. Therefore soil sterilization experiments were not conducted in subsequent seasons.

SPRAYING EXPERIMENTS.

Methods.—Corms of the variety Picardy were planted in rows of 100 corms according to ordinary commercial practices. The experiments were sprayed in randomized blocks, each row of 100 corms constituting a single plot. There were four replicates of each treatment and the same number of unsprayed plots.

The plots were dug six weeks after flowering and placed on wire-netting stretchers in the same order as the position of the plots in the field. The scales were removed from the corms after six weeks' storage and the number of infected corms determined.

Results (1940-41 season).—Lime sulphur 1 in 40 and 6:4:40 Bordeaux mixture were tried in that season. Agral II. was added to the sprays at the rate of 1 in 2,000, and good wetting of the foliage was obtained. Spraying was commenced one week after flowering, as foliage infection does not occur before flowering under Kalorama conditions.

Lime sulphur was ineffective and lesions developed on the sprayed plants. Bordeaux mixture prevented foliage infection for a fortnight after application, but later some lesions developed as the spray washed off the leaves.

Table 7 shows the percentage of infected corms:—

TABLE 7.

—			Unsprayed.	Bordeaux.	Lime Sulphur.
Percentage	..	..	23%	26·8%	24·5%
Angle	..	..	28·66°	31·15°	29·68°

The F value was determined and it was shown that the differences were not significant. However, it was felt that this could have been due to an insufficient number of applications of Bordeaux, and therefore a further spraying experiment was conducted in the 1941-42 season.

In that season 6:4:40 Bordeaux mixture, plus 1 in 2,000 Agral II., was applied at weekly, fortnightly, and monthly intervals, copper oxychloride ("Soltosan") at the rate of 3 lb. in 40 gallons, plus 1 in 3,000 Agral II. at fortnightly intervals, and a commercial copper dust ("Coppodust") at fortnightly intervals, were tried.

The copper oxychloride caused slight foliage injury, and did not prevent leaf infection. Copper dust did not cause injury but was ineffective. Bordeaux was effective in reducing the number of leaf lesions in the plots that were sprayed at weekly and fortnightly intervals. It delayed infection in plots sprayed at monthly intervals but did not prevent its development before the corms were dug.

Table 8 shows the percentage of infected corms. Analysis by the F value showed that the differences were not significant:—

TABLE 8.

	Unsprayed.	Bordeaux Weekly.	Bordeaux Fortnightly.	Bordeaux Monthly.	Soltosan.	Coppodust.
Percentage ..	2.5%	8.4%	6.1%	4.0%	4.8%	4.4%
Angle	9.17°	10.83	14.23°	11.46°	12.60°	12.07°

In this season the percentage of infected corms on the untreated plots was low, and the experiment was not therefore entirely conclusive. However, no evidence of possible control by spraying was obtained for the second successive year, and therefore spraying experiments were not conducted in subsequent seasons.

TREATING THE CORMS AT DIGGING TIME.

Dipping of corms, bulbs and tubers is usually conducted during the dormant period before planting, with the object of destroying diseases present on the surface of the corm. However, this would not be effective against the *Botrytis* disease of the gladiolus and therefore experiments were conducted to find a method of preventing entry of the disease into the corms.

L. Hawker (25) tried dipping narcissus corms in cold formalin at digging time but it did not prevent infection with *Botrytis narcissicola*. She found, however, that cold formalin, brassisan, folosan, and ceresan reduced losses due to *Fusarium bulbigenum*. F. Weiss *et al* (57) found that mercury compounds, particularly ethyl mercuric chloride and ethyl mercuric phosphate, were effective in preventing *Fusarium* basal rot of narcissus. A two-minute dip was as effective as longer treatments. The treatment was most effective if given immediately after digging. They found that the treatments caused injury to the flower buds in

subsequent crops, and they did not achieve a practical compromise between effective control and no flower injury. A number of treatments at digging time have been tried against *Botrytis* of the gladiolus.

Methods.—After digging, the corms were washed free of soil with a water spray and then counted into batches of 100. They were then placed in light hessian bags and dipped in the fungicidal solutions. After draining they were then spread out on wire-netting stretchers and stored on racks for drying. There were four replicates of each treatment and they were arranged on the stretchers in a randomized block arrangement.

After storage for six weeks the scales were removed and the number of infected corms determined.

Results (1940-41 season).—Dipping treatments tried were lime sulphur 1 in 20 for six hours and copper sulphate 2 per cent. for 24 hours. Another series was dusted with penta-chloro-nitro-benzene ("Folosan"). The variety Wolfgang von Goethe was used for the experiments. Gram and Thomsen (20) found 2 per cent. copper sulphate effective in controlling *Botrytis tulipae*. Pentachloro-nitro-benzene was found by Smieton and Brown (49) to control *Botrytis cinerea* on lettuce.

TABLE 9.

			Untreated.	Lime Sulphur.	P.c.n.b.	Copper Sulphate.
Percentage	..	..	4.5%	9.3%	2.0%	No count possible
Angle	..	..	12.27°	17.71°	8.00°	

The F value was determined and the differences found to be non significant.

Copper sulphate caused severe injury and no count of infected corms was possible.

Neither of the other treatments caused any significant reduction in the number of infected corms.

Results (1941-42 season).—In that season shorter dipping times were employed to guard against similar injury to that produced by the copper sulphate treatment. The variety Hindenburg's Memory was used for the experiment. 6:4:40 Bordeaux mixture, plus 1 in 2,000 Agral II., for half an hour; lime sulphur, 1 in 40, plus 1 in 2,000 Agral II., for half an hour; mercuric chloride (corrosive sublimate), 1 in 1,000 for 1 hour, and a commercial brand of copper dust "Coppodust" were tested.

Table 10 shows the number of infected corms:—

TABLE 10.

	Untreated.	Corrosive Sublimate.	Bordeaux.	Cu Dust.	Line Sulphur.
Percentage	5·9%	0·6%	3·4%	3·2%	12·4%
Angle	14·02°	1·43°	10·70°	10·24°	20·66°

Whole experiment highly significant by F test.

Difference for significance at 1 per cent. level .. 3·48°

Difference for significance at 5 per cent. level .. 2·48°

The method of analysis of variance described by Snedecor (51) was used.

Both corrosive sublimate and copper dust produced a reduction in infected corms which was significant at the 1 per cent. level, though the control exercised by copper dust was not sufficient to be of much commercial value. Corrosive sublimate exercised good control but caused a superficial injury, in the form of a hard brown depression along the base of the scales on the corms. However, when these corms were grown the plants were normal and produced normal flowers. Bordeaux mixture caused a reduction in the number of infected corms which was significant at the 5 per cent. level, but it was not sufficient to be of commercial value.

The number of infected corms produced in the lime sulphur treated corms was significantly higher than the untreated. This was apparently due to the fact that the treatment delayed the drying of the corms and they remained susceptible for a longer period than untreated corms.

Results (1942-43 season).—In this season corrosive sublimate, 1 in 1,000, plus Agral II, 1 in 2,000, for one minute and for 30 minutes; and Hortosan D.P. at the rate of 1 oz. in 5 gallons for two minutes and fifteen minutes were tested. The corms were placed in bags of cheese-cloth instead of hessian bags. The variety Picardy was used for the experiment.

Hortosan D.P. is a proprietary material containing 2·5 per cent. of mercury as an organic mercuric compound.

TABLE 11.

	Untreated.	Corrosive Sublimate 1 minute.	Corrosive Sublimate 30 minutes.	" Hortosan " 2 minutes.	" Hortosan " 15 minutes.
Percentage	46·7%	4·1%	1·8%	6·0%	0·6%
Angle	43·13°	11·64°	12·64°	14·12°	1·43°

The whole experiment was shown to be highly significant by the F test.

Difference for significance at 1 per cent. level .. 5·85°

Difference for significance at 5 per cent. level .. 4·07°

All treatments caused a significant reduction in the number of infected corms. Hortosan D.P. for fifteen minutes was significantly better than all other treatments. There was no significant difference between the two corrosive sublimate treatments. No injury was caused by any of the treatments.

Results (1943-44 season).—The primary object of the experiment in this season was to test the effectiveness of other proprietary organic mercurials, and to repeat tests on Hortosan D.P. for fifteen minutes and corrosive sublimate, plus 1 in 2,000 Agral 11., for two minutes. Aretan (containing 3.5 per cent. mercury as methyl-oxy-ethyl-mercuric chloride used at the rate of 4 oz. in 10 gallons) and Zetan (synonymous with New Improved Semesan Bel., containing 12 per cent. hydroxy mercuric nitro phenol and used at the rate of 1 lb. to 10 gallons), were also tested. A dipping time of fifteen minutes was used for both materials.

The variety Picardy was used for the experiments and the corms were dipped in light hessian bags.

TABLE 12.

—		Untreated.	"Hortosan" D.P.	"Zetan."	"Aretan."	Corrosive Sublimate.
Percentage	..	47.5%	8.4%	10.5%	16.9%	15.6%
Angle	..	43.55°	16.84°	18.89°	24.27°	23.23°

Whole experiment highly significant at 1 per cent. level.

Difference for significance at 1 per cent. level .. 8.31°

Difference for significance at 5 per cent. level .. 5.93°

All treatments caused a significant reduction in the number of infected corms. There was no significant difference between treatments at the 1 per cent. level, but at the 5 per cent. level Hortosan D.P. was significantly better than Aretan or Corrosive sublimate.

REPLENISHMENT OF SOLUTION.

From an economic point of view it would be desirable to be able to use the same solution for several batches of corms. It is obvious that some reduction in strength of the dipping solution will occur after each batch of corms. Gilmore and Robinson (18, 19) investigated the loss in strength of corrosive sublimate solutions after dipping seed potatoes.

Therefore in 1944 a dipping experiment was conducted to determine the loss in strength of Hortosan D.P.

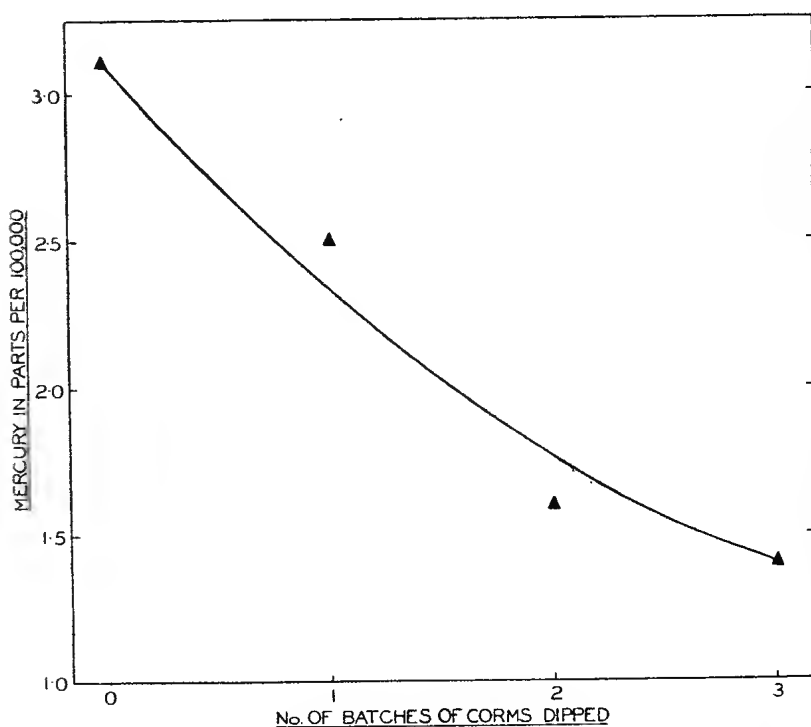
Method.—Four gallons of Hortosan D.P. solution was prepared and a sample of the solution taken. Then three successive batches of 200 washed corms were dipped in light hessian bags. Each dipping was for exactly fifteen minutes. After each dipping, samples of the solution were taken. The mercury content of the solutions was determined by Mr. W. Jewell, Agricultural Research Chemist of the Victorian Department of Agriculture.

Results.—The results are shown in Table 13 and are presented graphically in Text fig. 3:—

TABLE 13.

	Original.	After One Batch of Corms.	After Two Batches of Corms.	After Three Batches of Corms.
Mercury in parts per 100,000	3.1	2.5	1.6	1.4

EFFECT OF DIPPING SUCCESSIVE BATCHES OF CORMS IN HORTOSAN D. P.



In the figure a curve has been fitted to the points. It is not surprising that the points do not fall exactly on the curve, since variability would be expected because of variation in the size of the corms and the amount of soil on the corms.

Gilmore and Robinson (18) have pointed out a similar variability when dipping potato tubers in corrosive sublimate. Because of this factor they developed a field method (19) for determining the amount of corrosive sublimate necessary to replenish the solution.

Unfortunately, no similar method could be developed for organic mercurials, as the analysis of these materials is essentially a laboratory determination.

It is realized that any general recommendations cannot be accurate, but if the dip is not used for more than three or four batches of corms the error would not be of great practical importance. A calculation based on the graph of the results was made, and it was found that $\frac{1}{2}$ oz. of Hortosan D.P. should be added after dipping each batch of 500 corms in 10 gallons of a solution of 2 oz. of Hortosan D.P. per 10 gallons for fifteen minutes.

EXPOSURE OF CORMS TO VOLATILE FUNGICIDES.

The first use of a volatile material against a fungal disease was in the control of Blue Mould (*Pecronospora tabaci*) of tobacco (Angell *et al* (1)). Subsequently, other related compounds have been used (59).

Various volatile materials were tested against the *Botrytis* of *gladiolus*. In preliminary tests the materials were tested against the fungus itself, using a slight modification of the method described by Oserkowsky (42). The effect of promising materials on healthy corms was then determined.

Methods.—Potato dextrose agar was poured into sterile 4-in. petri dishes. Before the medium had set a sterile 1-in. petri dish lid was placed in the centre of the medium. The plates were then inoculated with *Botrytis* and incubated for five days. One ml. of the volatile material was then pipetted into the small petri dish. The cultures were examined after 24, 48, and 72 hours and a small portion of the mycelium transferred to a potato dextrose agar slope. The slopes were then incubated and examined for growth.

Results.—The results are shown in Table 14:—

TABLE 14.

Chemical.	Results.		
	24 Hours.	48 Hours.	72 Hours.
Benzol	++	++	++
Toluene	++	++	++
Dioxan	--	--	++
Paradichlorbenzene ..	--	--	++

++ Colony flattened. No growth from subculture.
 +- Colony flattened. Growth from subculture.
 -- Colony unaffected. Growth from subculture.

Benzol and toluene were therefore effective in killing the fungus after exposure for 24 hours. Dioxan and paradichlorobenzene did not have any visible effect after exposure for 48 hours. After exposure for 72 hours both materials caused flattening of the colonies, but did not cause death of the fungus.

To determine the effect of exposure of gladiolus corms to benzol vapour, six corms of the variety, Mrs. S. A. Errey, were enclosed in a closed tin, with a layer of benzol at the bottom, for 24 hours. The corms were then planted.

The plants produced showed distortion, and the flowers which developed were severely distorted. On digging the plants, it was found that the corms produced were abnormal in shape (Plate V., fig. 10).

This method of treatment did not show promise of success, and experiments of this type were not continued.

TIME OF DIGGING.

Species of *Botrytis* have been frequently shown to be favored by cool humid conditions (2, 25). It was, therefore, anticipated that if corms were dug before the weather became cool and humid they would possibly escape the disease.

Miss Hawker found that narcissus bulbs showed heavier losses, due to *Botrytis narcissicola* at low or moderate, rather than higher temperatures.

Methods.—Corms of the variety Picardy were planted in rows containing 100 corms. Four rows were planted at each of three periods separated by a month. They were dug six weeks after flowering.

The corms were then placed on wire-netting stretchers. After storage for six weeks the scales were removed from the corms, and the number of infected corms determined.

Results.—The corms were dug on the 2nd April, 23rd April, and on the 7th May. The number of infected corms is shown in Table 15:—

TABLE 15.

	Time of Digging.		
	Early.	Midseason.	Late.
Percentage	0·5%	27·1%	21·7%
Angle	4·06°	31·35°	27·72°

Whole experiment highly significant by F test.

Difference for significance at 1 per cent. level .. 6·77°

Difference for significance at 5 per cent. level .. 5·15°

Therefore by digging the corms early the disease was almost entirely avoided. Unfortunately only rainfall data are available for the Kalorama district and no data on humidity or temperature was obtained. A study of rainfall data for Kalorama in 1941 showed that some rain fell on each of the four days after digging the early plants, but then no further rain fell for ten days. Apparently these good drying conditions were unfavorable for the disease.

A study of rainfall data for Kalorama in the succeeding four seasons showed that if corms are dug before the second week of March, the rainfall is unlikely to be heavy following digging and therefore there is little chance of infection. All corms dug later should be dipped.

These observations were confined to the Kalorama district and no general recommendations are possible.

VARIETAL RESISTANCE.

Answers to inquiries made among growers suggested that certain varieties were resistant to the disease. Therefore an experiment was conducted in the 1940-41 season to determine the relative susceptibility of various varieties to the disease.

Methods.—The corms were planted in rows, each containing 100 corms. There were four replicates of each variety and the plot was laid down as a randomized block. The corms were dug six weeks after flowering and placed on wire-netting stretchers in the same relative position as the plots in the field. After storage for six weeks the scales were removed and the percentage of infected corms determined.

Results.—The results are shown in Table 16:—

TABLE 16.

	Variety Used.						
	Golden Goddess	Pelegrina	Wolfgang v. Goethe	Miss New Zealand	Gate of Heaven	Picardy	Red Lory
Percentage ..	17·6%	1·5%	15·7%	0%	18·9%	27%	4·4%
Angle ..	25·04°	7·01°	23·35°	0°	25·79°	31·33°	12·18°

Whole experiment highly significant by F test.

Difference for significance at 1 per cent. level .. 3·53°

Difference for significance at 5 per cent. level .. 2·58°

Pelegrina, Miss New Zealand, and Red Lory all showed resistance to the disease, but Miss New Zealand was significantly more resistant than the other varieties, and Pelegrina was significantly more resistant than Red Lory.

It is interesting to note that the foliage of *Pelegrina* was severely infected with the fungus and had almost completely died down before digging. On the other hand *Picardy* showed some leaf spotting, but less than any other variety tested.

According to growers' reports, *King Lear*, *Elinora*, *Mrs. S. A. Errey*, *Black Opal*, *Champlain*, *Don Bradman*, and *Rose Dawn* are also resistant to the disease.

Discussion.

Botrytis corm rot is a disease which is favored by cool, humid conditions. Growers can therefore avoid infection of the corms by planting early, so that the corms are dug in the early autumn. However, as most growers desire to produce flowers for the cut-flower trade, in addition to corms, they prefer to plant portion of their stock at intervals throughout the season, so that all their flowers are not produced at the one time. Therefore they must have recourse to the other control measures described. Apart from the hope that in the future a large number of resistant varieties may be produced, the knowledge that certain popular varieties at present grown are resistant, will enable the grower to avoid the expense of unnecessarily dipping these varieties.

The results obtained with various dips applied at dipping time, show that very good control may be obtained with Hortosan D.P. Slightly less effective control can be obtained with corrosive sublimate, plus Agral 11., and with Aretan. Zetan also gives good control. The higher degree of control obtained with Hortosan D.P. in the 1942-43 season than in the 1943-44 season may be due to the fact that the corms were dipped in muslin bags in the earlier season, and in hessian bags in the latter. Growers should preferably use muslin bags. It must be stressed that the corms be well washed before dipping, as many organic mercurials are inactivated by soil. Dipping must be carried out as soon as possible after digging. The suggestion for replenishing the Hortosan dip is tentative, and growers should not use the replenished dip for more than three or four batches of corms.

Observations suggest that the main method of overwintering of the disease is on infected corms. These usually bear abundant sclerotes and, as has been shown, these germinate under certain conditions to produce conidia. The conidia produced from this source would then infect flowers left in the field, and, as abundant conidia are rapidly produced on flowers, a heavy spore load would be rapidly built up. Growers should therefore destroy infected corms by deep burial or by burning. They should not leave unwanted flowers in the field, but should cut them, and destroy them by burning or burial.

Good storage conditions are important and the maximum of ventilation should be provided. This is best achieved by using wire-netting stretchers arranged on racks. However, it is felt that good storage conditions, and attention to sanitation, as recommended in the preceding paragraph, will not eliminate the necessity for dipping, but rather all these measures are complementary.

Acknowledgments.

The writer is greatly indebted to Messrs. Rowse, of Kalorama, for providing material for experimental purposes, and for valuable assistance with the field work.

Mr. W. Jewell, of the Victorian Department of Agriculture, conducted the analysis of mercury-dipping solutions, and Dr. H. C. Forster, of the same Department, prepared the statistical analysis on the relation between vitamins and increasing dextrose content on the growth of the fungus. This work was conducted at the Biological Branch, Department of Agriculture, Victoria.

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Explanation of Plates.

PLATE V.

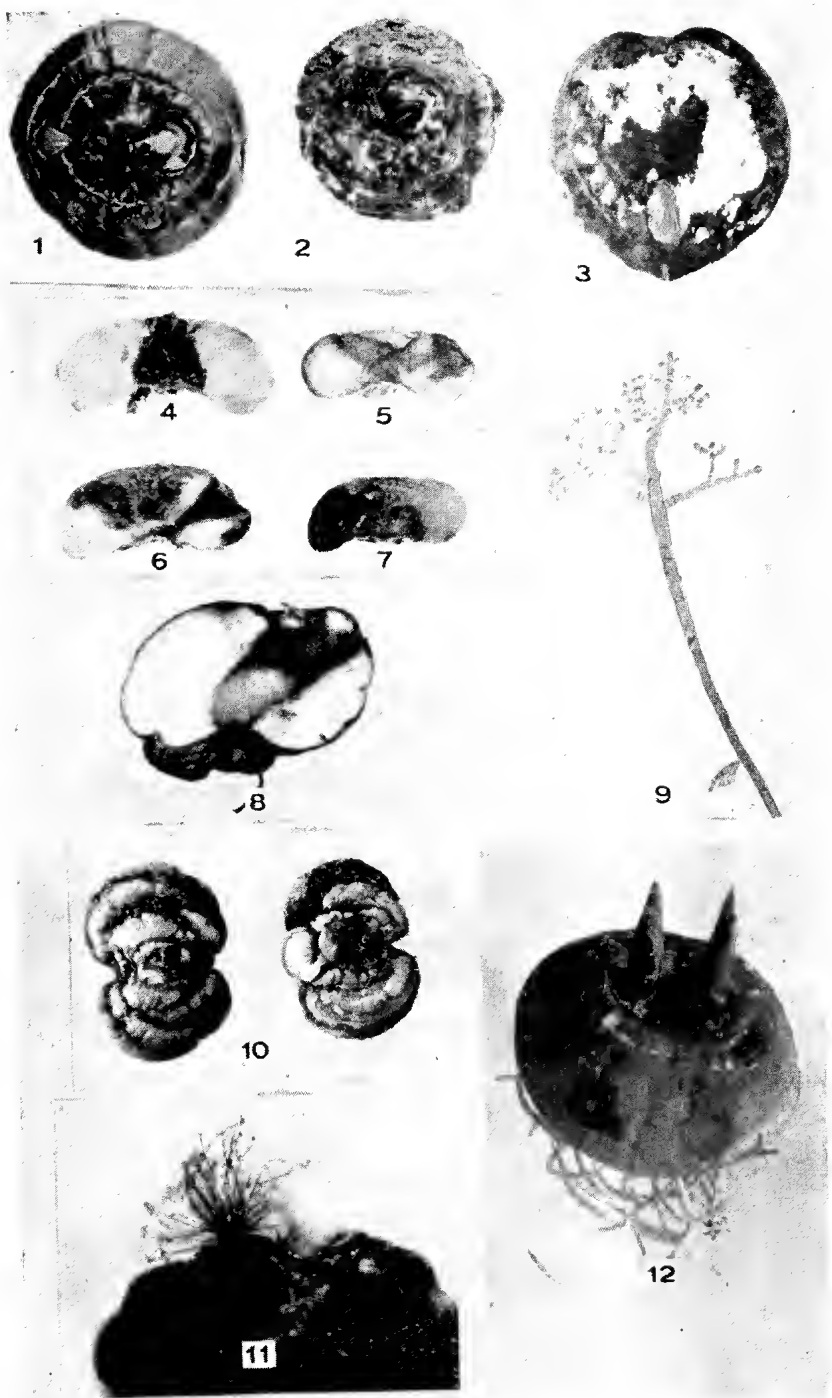
- FIG. 1.—Slightly infected corm.
 FIG. 2.—Mummified corm. Note the sclerotes.
 FIG. 3.—Infected corm showing mycelium and sclerotes of *Botrytis*.
 FIGS. 4-7.—Sections of corms showing progressive stages of infection.
 FIG. 8.—Section of a corm showing infection commencing at the top of the core.
 FIG. 9.—Conidiophore of *Botrytis* $\times 100$.
 FIG. 10.—Corms showing the effect of benzol on the growth of the corm in the subsequent crop.
 FIG. 11.—The development of conidia from a sclerote $\times 10$.
 FIG. 12.—Artificial infection of a corm with *Botrytis*.

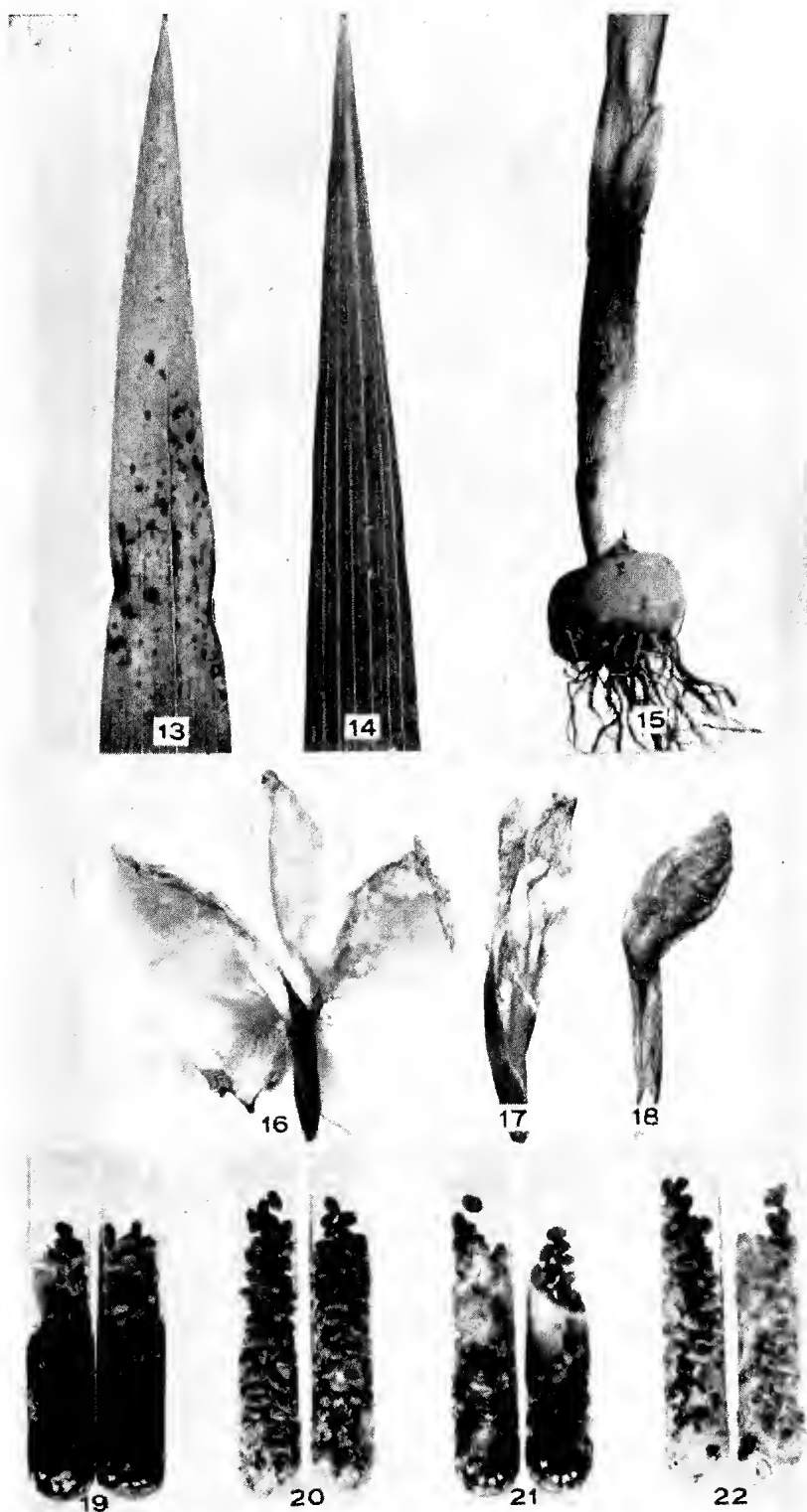
PLATE VI.

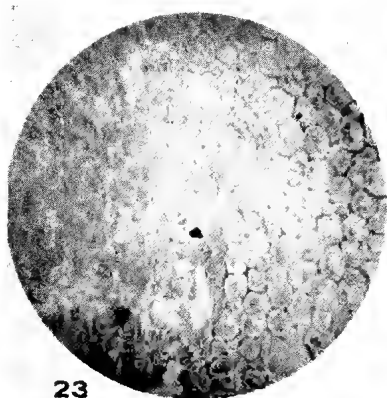
- FIG. 13.—Leaf infection with *Botrytis*.
 FIG. 14.—Leaf from plant of same maturity as Fig. 13, but the plant was sprayed with Bordeaux mixture at flowering time.
 FIG. 15.—Collar rot caused by *Botrytis*. Note the sclerotes on the collar region of the plant.
 FIGS. 16-18.—Progressive stages of infection of flowers with *Botrytis*. Note the conidia on Fig. 18.
 FIGS. 19-22.—The effect of light on *Botrytis*. The tubes illustrated in 19 and 20 were held at 23°C ., but 19 was exposed to light and 20 kept away from light. Those illustrated in 21 and 22 were held at room temperature, and 21 exposed to light and 22 kept away from light.

PLATE VII.

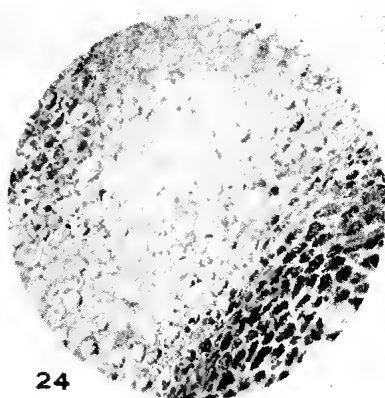
- FIG. 23.—Section showing margin between healthy and diseased tissue. Note the accumulation of starch in infected tissue and the sharp line of demarkation between the healthy and diseased tissue. Stained with iodine and erythrosin. $\times 35$.
 FIG. 24.—Section showing an intermediate layer of low starch content between the healthy and diseased tissue. Note the accumulation of starch in the diseased tissue (lower right). Stained with iodine and light green. $\times 35$.
 FIG. 25.—Freehand section through an arrested lesion. Note the suberised layer between the starch free layer (lower) and the normal tissue. Stained with iodine and Sudan III. $\times 42$.
 FIG. 26A.—Longitudinal section through an infected vascular bundle $\times 35$.
 FIG. 26B.—Enlargement of portion of 26A, showing apparently unaffected Xylem tissue and almost completely disorganized phloem tissue. Stained with Haidenbain's Haematoxylin and light green. $\times 85$.
 FIG. 27.—Transverse section through an infected vascular bundle. Note the disorganization of infected tissue and the sharp line of demarkation between healthy and diseased tissue. Stained with Haidenbain's Haematoxylin and light green. $\times 35$.
 FIG. 28.—Tangential section through an infected vascular bundle. Note the heavy fungal infection of the vascular bundle, and the absence of hyphae in the adjacent parenchymatous tissue. Stained with Haidenbain's Haematoxylin and light green. $\times 35$.



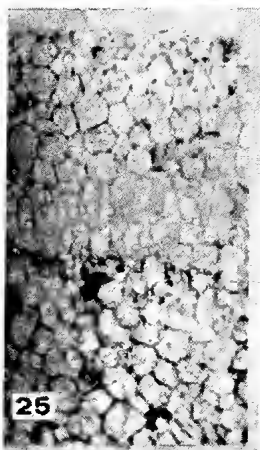




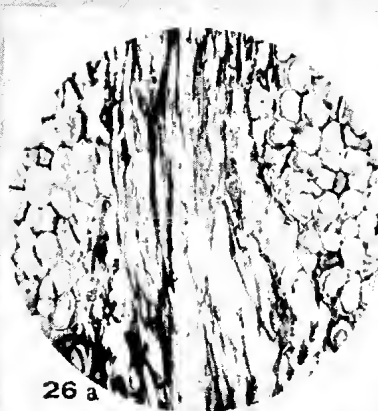
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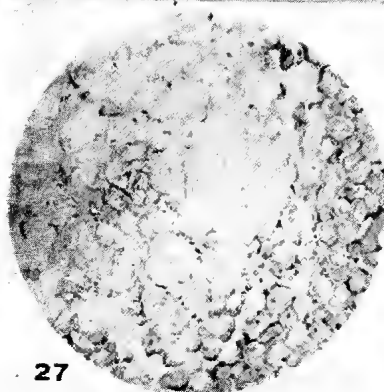
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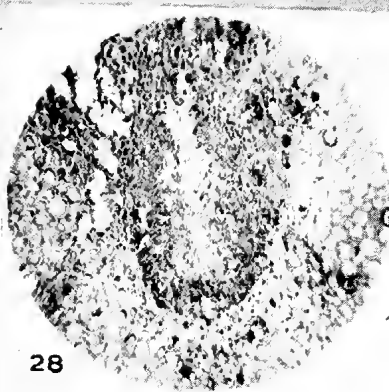
26 a



26 b



27



28

ART VI.—*Chonetidae from the Palaeozoic Rocks of Victoria and their Stratigraphical Significance.*

By EDMUND D. GILL, B.A., B.D.

[Read 14th December, 1944; issued separately 10th December, 1945.]

Summary.

A survey is made of all the known Chonetidae from the Palaeozoic rocks of Victoria. Comments are made on species of *Chonetes* and *Anoplia* already described, and the following new species are erected—*Chonetes bowicæ*, *C. productoida*, *C. killarensis*, *C. psiloplia*, *C. ruddockensis*, *C. taggertyensis*, and *C. gaskini*. The affinities of these forms with those found elsewhere are given, and their stratigraphical significance commented upon. A subdivision of the Yeringian Series is proposed.

Introduction.

Fossils of the brachiopod family Chonetidae (the classification of the *Fossilium Catalogus* is adopted) are known in Victoria only from Silurian and Devonian rocks, and they belong to the two genera *Chonetes* (*sensu stricto*) and *Anoplia*. The following table summarizes our knowledge of the occurrence of this group:—

Series.	Age.	Genus and Species.
Buchan Beds ..	Middle Devonian ..	<i>Chonetes australis</i> McCoy
Bindi Beds ..	Middle Devonian ..	<i>C. australis</i> McCoy <i>C. gaskini</i> , sp. nov.
Yeringian ..	Lower Devonian (in part at least)	<i>C. bowicæ</i> , sp. nov. <i>C. cresswelli</i> Chapman <i>C. killarensis</i> , sp. nov. <i>C. productoida</i> , sp. nov. <i>C. psiloplia</i> sp. nov. <i>C. robusta</i> Chapman <i>C. ruddockensis</i> , sp. nov. <i>C. taggertyensis</i> , sp. nov. <i>Anoplia australis</i> Gill <i>A. withersi</i> Gill
Melbournian ..	Lower Ludlow (in part at least)	<i>Chonetes melbournensis</i> Chapman

The Devonian genera *Eodcvonaria* and *Chonostrophia* have not been found in Victoria. Fig. 1 attempts to represent diagrammatically the relationships of the various genera of the family Chonetidae, and of that family to the closely-related family Productidae.

Discussion of the Genus *Chonetes*.

Class BRACHIOPODA Dumeril.

Family CHONETIDAE Hall and Clarke, 1895.

Genus ***Chonetes*** Fischer de Waldheim, 1837.

GENOLECTOTYPE *Chonetes* sp. Fischer = *C. variolata* D'Orbigny, 1842, as interpreted by De Koninck, 1847 (quoted from *Fossilium Catalogus*).

ETYMOLOGY OF GENERIC NAME.—The name of the genus is derived from the feminine Greek noun "chone," a funnel, but the form "chonetes" is masculine, and so strictly speaking all the trivial names should be masculine in agreement. Such they were made by many early writers, but feminine forms have been established by consistent recent usage, and it would be confusing now to change all the names.

DIAGNOSIS OF THE GENUS.

Inequivalve, equilateral chonetids, with a straight hinge-line, and a row of hollow spines along the ventral cardinal margin. Ventral valve convex; dorsal valve flat to concave. Interior ventral valve with two small teeth, unsupported by dental lamellae. Cardinal area narrow and smooth. Pedicle obsolescent as shown by closure of pedicle opening by a pseudo-deltidium. Muscle impressions non-dendritic. Surface usually covered with radiating striae or ribs; rarely smooth. Interior of shells commonly papillose in the pallial region.

PHYLOGENETICS.

The genus *Chonetes* is a simple expression of the forms previously grouped in the large family Productidae. It is the stock from which the Upper Palaeozoic productids were evolved. *Chonetes* appeared in the late Ordovician whereas *Productella* did not appear till the Devonian. The genera *Chonetes*, *Productella*, and *Productus* are very similar, differing characteristically in their degree of spinosity. The spines were probably a means of attachment compensating for a deficient or obsolescent pedicle (Beecher, 1898, p. 351). They may be regarded as a mark of group gerontism. In his diagnosis of the genus *Chonetes*, Schuchert writes of the spines (1913, p. 389), "These are prolongations of tubes which penetrate obliquely the substance of the shell along the hinge-line." Practically all the Victorian species have their spines at right angles to the hinge-line, and in a number of cases it is known definitely that the tubes penetrated the shell substance at right angles and not obliquely. A number of species have been noted both in European (e.g., *C. margaritacea*) and American (e.g., *C. setigera*) deposits which have their spines set at right angles to the hinge-line.

One visualizes the Chonetidae arising from Strophomenids of the type of *Chonetoidea* and *Sowerbyella*, which are quite chonetoid in structure but lack spines. *Eochonetes* (Reed, 1917) is a plectambonitin with spines. Breger (1906) erected the sub-genus *Eodevonaria* to accommodate the denticulate forms of *Chonetes*. Denticulation is so important a feature phylogenetically that Schuchert and Le Vene (1929) justifiably accorded *Eodevonaria* generic status.

Spines are the principal generic feature of *Chonetes*, and are also of considerable value for specific determination. Hall (1892) writes, "Their comparative strength or direction often furnishes means for specific determination, but I have not been able to satisfy myself that the number of spines on the hinge-line is of specific importance." The investigation of the Victorian forms suggests that the number of spines is constant in a species. As Hall says, the nature of the spines is of specific importance. For instance *C. robusta* and *C. killarensis* have a somewhat similar outline and ornament, and both possess a median sulcus, but the spines of each species are very different. In *C. robusta* they are long, thick, and straight, whereas in *C. killarensis* they are short, thin, and sinuous. Evidently there was rapid variation in this specialization of the genus.

CLASSIFICATION.

De Koninck (1847) classified *Chonetes* in his monograph according to the surface ornament, as follows:—

A surface ornée de plis concentriques	1. Concentricae.
plus de 100 côtes lisses	2. Comatae.
moins de 100 mais plus de 30 côtes lisses	3. Striatae.
de moins de 30 côtes lisses	4. Plicosae.
de côtes rugueuses	5. Rugosae.

In the light of later studies such a classification appears rather arbitrary and not based on genetic relationships, but Paeckelmann (1930) has created sub-genera based on these divisions. All the Victorian forms come within the class Striatae of De Koninck, i.e., the *Chonetes sensu stricto* of Paeckelmann.

Grabau and Shimer (1909) have classified *Chonetes* according to the presence or absence of ornament, and the presence or absence of a sulcus, as follows:—

- A. *Chonetes* with radiating striae.
 - (a) Ventral valve with a median sulcus.
 - (b) Ventral valve without a median sulcus.
- B. Smooth *Chonetes*.

Group A is further sub-divided by Grabau and Shimer according to the number of spines carried on the ventral cardinal margin. All the species described in this paper come within Group A. *C. cresswelli*, *C. robusta*, and *C. killarensis* come within the sub-section "a," and the rest of the species in sub-section "b."

Prendergast (1944) has recently dismissed Schuchert's 1913 classification of productids based on means of attachment as "purely arbitrary," arguing that it "makes no allowance for a similarity of external form due to growth under similar environmental conditions" (p. 10). This view is expressed more specifically in the statement that "Given the condition necessary for spine development, that is, a plentiful supply of CaCO_3 , any species will probably develop spines in the same position in all its members. The inclination of the spines to the body surface will depend upon the hardness of the sea-floor, arising at a high angle where the substratum is soft and being adherent where it is hard. In modern lamellibranchs the temperature of the water has a marked effect on the thickness of the shell, the Arctic forms having a thick shell and the warm water forms of the same species a shell thin almost to fragility. The difference between the Irwin forms, thin with short spines of small bore and those from Mt. Marnion, thick-shelled with heavy spines, of *Taeniothærus subquadratus* (Morris) is possibly due to the difference in temperature of the sea at the two localities."

From a consideration of Prendergast's statements, the following points emerge:—

(1) Schuchert's 1913 classification is challenged but no mention made of his 1929 revised classification in the *Fossilium Catalogus*.

(2) Phenotypes result from interaction between genetic constitution and environment. Imagine, for instance, a *Chonetes* individual with genes for spines of a certain size and shape, orientated to the shell in a certain way. That such genes existed may be justly inferred from the fact that spines of a certain character are always found on individuals of the same species. If the optimum amount of calcium salts (or the ability to assimilate them) for building such spines in such a way is not present, then spines will develop, but not of the strength that would otherwise be attained. The whole exoskeleton will show signs of calcium starvation. Paucity or plenty of calcium salts will not determine the absence or the presence of spines, but their degree of development. If calcium salts were absent altogether, there would be no exoskeleton and no shellfish. If the calcium supply is low, then the whole exoskeleton will suffer by the shell being thin and the spines weak. This is where Prendergast's argument breaks down. However abnormal the conditions be, the means of attachment of the shell, viz., the spines, will be present, and so available as an objective means for the classification of species, genera, &c.

(3) The means of attachment represent a line of rapid evolution for the group under discussion. *A priori*, such lines of rapid evolution should constitute good bases for classification. The wide variety in the nature of the spines in the numerous

species of *Chonetes* indicates that there must have been a high mutation rate operating. The spines on the exoskeletons of some modern shells seem to have no biological significance. They may be mutations which remain because they are neither an advantage nor a disadvantage to the animal. However, the spines of the *Chonetes-Productus* series appear to have played an important part by keeping the animal above the muddy sea-floor where the water would be clearer and the supply of food more certain. The group was a very successful one, maintaining itself over a vast stretch of time, and existing in prolific numbers. The spinosity of these forms was apparently an important biological feature. The series ended up with the *Richthofeniidae*, which lost the power to elevate themselves by spines and elevated themselves above the sea-floor by thickening the ventral valve until they looked like cyathophylloid corals.

(4) Prendergast's reference to forms lacking calcium because in warm tropical seas is not easy to follow. Coral reefs are tremendous accretions of calcium, and such shells as the big clams indicate the withdrawal from tropical and sub-tropical seas of very large amounts of lime. The biggest and most extravagantly ornamented shells come from tropical seas. Many extensive beds of limestone have been laid down in tropical waters. These facts do not suggest paucity of calcium in tropical waters, or lack of ability on the part of marine organisms in those areas to assimilate calcium.

(5) Schuchert's 1929 classification separates off the Chonetidae as a distinct family from the Productidae. The difficulty in taxonomy is that no systematic classification fits perfectly the complex variations of nature itself. The systematist's task is to devise a classification which represents as closely as possible the known facts. The early chonetids are closely allied to the *Plectambonitiinae*, being distinguished from them chiefly by the presence of cardinal spines. Similarly, the later chonetids are very closely allied to the productids, which are distinguished by their increased spinosity and dendritic muscle impressions. The productids constitute a clearly-defined group of an increasing number of genera, very widely distributed, and most prolific. "They produced the most numerous, the most varied, the most widespread and the largest brachiopods in the late Palaeozoic" (Raymond, 1939). The chonetids likewise form a biologically distinct, numerically large, and racially prolific group surviving in strength through the major part of the Palaeozoic (*vide* fig. 1), and still maintaining its strength after giving rise to the productids. In my opinion, furthermore, the early chonetids are quite as closely allied to the *Srophomenidae* as the later chonetids are to the *Productidae*, and therefore there are as adequate grounds for separating the chonetids from the productids as there are for separating the chonetids from the *srophomenids*. I

therefore agree with Schuchert's suggestion that they be represented as two separate families—the Chonetidae and the Productidae.

ADAPTATIONS.

Most of the species of *Chonetes* from Victoria are fairly thin-shelled forms, and usually there is a direct correlation between the weight of the shell and the strength of the spines. For example, *C. melbournensis* is a light form with fine spines, whereas *C. robusta* has heavier valves and stronger spines. The mechanics of these shells are very interesting. The spines are hollow, which affords strength with the lightness needed for a semi-floating organism; likewise corrugations of the shell give strength with lightness. The shells are usually flattish or concave, and so adapted to the semi-floating (i.e., not rigidly fixed) condition of an organism attached to a sub-stratum. The small space between the two valves indicates that the animal was slender, and so again adapted by its lightness to the particular place this genus had in the marine ecology of Palaeozoic times.

SOME CHARACTERISTICS OF THE VICTORIAN FORMS.

Reference has already been made to the setting of the spines on our forms at right angles to the hinge-line. *Chonetes maoria* Allan from the Reefton (Lower Devonian) Beds of New Zealand also has its spines inserted at right angles as is to be seen on a specimen in the National Museum, Melbourne.

Three species described in this paper (*C. robusta*, *C. cresswelli*, and *C. killarensis*) have a well-defined mesial sulcus in the ventral valve. The biological advantage of this would be the increased area for muscle attachment; perhaps also the sulcus would have a similar action to a keel and help to keep the animal floating evenly. The same feature has been noted in *C. variolata*, *C. verneuilliana*, *C. mesoloba*, *C. coronata*, *C. lepida*, *C. arcuata*, *C. mansuyi*, and *C. ningpoensis*. Reed (1921) describes this feature in a variety of *C. sarcinulata*. In the Victorian forms the sinus is a constant character of the species named, whereas it is claimed to be present in *C. acutiradiata* only sometimes, and it is not found in all the specimens named *C. maoria*. A mesial sinus is common in the Productidae.

Another feature of interest is the differentiated margin, such as found in *C. taggertyensis*, a similar phenomenon to which has been described in *C. sarcinulata*, *C. maoria*, *C. coronata*, and *C. syrtalis*. The structure is interesting phylogenetically in view of various modifications of the margin of the shell found in other Strophomenaceae, such as the deflected margin in *Leptaena* and *Strophonella*, variation in papillosity around the margin of the interior surface in *Chonetes*, variation in the external ornament around the margin of some species of *Productus*, and so on.

Notes on Species Previously Described.

CHONETES (CHONETES) MELBOURNENSIS Chapman.

Chonetes melbournensis Chapman, 1903, pp. 74-76, pl. XI., figs. 2-4.

TYPE MATERIAL.—Two syntypes. National Museum, Reg. No. 636, is the internal cast of a ventral valve in micaceous, bluish-grey, very fine-grained sandstone from "South Yarra Improvement Works." N.M., Reg. No. 1419, is the internal cast of a dorsal valve in hard, greyish-brown, very fine-grained sandstone from "Sewerage tunnel near old Fishmarket."

DESCRIPTION OF VENTRAL VALVE (No. 636).—This is a decorticated shell, small, slightly convex, flat on cardinal margins, measuring 5 mm. long and 8.5 mm. wide. The profile rises about .75 mm. above the plane joining the anterior and posterior margins. Surface with about 80 fine, radiating striae with some six more or less evenly-spaced, slightly stronger radii. The preservation does not allow of detailed examination of the fine striae, but where clearly discernible, increase is by bifurcation. Cardinal area narrow; cardinal angles a little more than right angles. Beak distinct, but not large, projecting just beyond the hinge-line. Elongate papillae present, orientated to the striae. (Not realizing that he was dealing with a decorticated specimen, Chapman described these impressions of papillae as pittings in the outer surface of the shell.) Muscle scars indistinguishable. No spines preserved.

DESCRIPTION OF DORSAL VALVE (No. 1419).—Small shell, very slightly concave, measuring 3.5 mm. long, and 6.5 mm. wide. Surface covered with numerous poorly preserved fine radiating striae, some few being a little more pronounced than the rest; a clearly defined linear depression runs down the whole length of the centre of the shell. Five long, very fine spines preserved from the ventral valve (two on one side of the umbo and three on the other), the longest being 2.5 mm.

COMMENT.—Examination of specimens other than the syntypes shows that *C. melbournensis* carries ten long, pointed spines, five on each side of the umbo; the spines are set at right angles to the hinge-line or curved outwards slightly. Examination of a number of specimens also shows that the interiors of both valves are covered with fine papillae, which are elongate, set in the inter-striate spaces, and orientated to the direction of the striae. The external ornament appears also on the interiors of the valves, but less distinctly, and is absent where the muscle scars are well developed.

In *C. melbournensis* there is a stronger rib down the middle of the ventral valve and a corresponding linear depression on the dorsal valve. This bipartition may be compared with the mesial

sinus found in a number of species of *Chonetes* (*vide* p. 131). Similar bipartition has been described in *C. novascotica* (McLearn, 1924) and *C. aroostookensis* (Clarke, 1907).

C. melbournensis is a valuable index fossil, but some care is necessary to ensure that specimens really do belong to this species. The author has noted a variety of forms which have been referred in collections to this species, but which do not conform to the type. Extensive collecting and intensive study will have to be undertaken to separate out these various forms and accord them their proper status. Sherrard and Keble (1937) recorded *C. melbournensis* from New South Wales. Mrs Sherrard kindly allowed me to examine these specimens. However, they are possibly small stropheodontids and certainly not *Chonetes*. Many stropheodontids simulate *Chonetes*, e.g., *Stropheodonta bipartita* (Chapman) from the Yeringian rocks of Victoria. Thomas (1937) has used *C. melbournensis* as a zone fossil in the series of sediments at Heathcote, but this form is not *Chonetes* either, if the specimens collected by Professor Hills from this horizon are the form to which Thomas refers. Like the New South Wales fossil, it is devoid of spines and only simulates *Chonetes* in its general form and ornament. The record of *C. melbournensis* from "Auburn" and "Balwyn, near Templestowe" (Chapman, 1914, p. 215) is also incorrect.

Affinities.—*C. melbournensis* is comparable with *C. novascotica* of the North American succession and *C. striatella* of the European succession. *C. novascotica* occurs in the Moydart (Lower Ludlow age) and the Stonehouse (Upper Ludlow age) of Arisaig, Nova Scotia (McLearn, 1924), and has also been recorded from the Missenden Bore in England (Straw, 1932). McLearn says (p. 65) that *C. novascotica* differs from *C. striatella* in the development of a stronger median stria on the ventral valve, which feature is also found in *C. melbournensis*. *C. novascotica* has the same number of spines as *C. melbournensis*, but they are minute, whereas those of the latter species are as long as three-quarters of the length of the shell. The surface of *C. novascotica* has more numerous striae, but forms with coarser ornament are known (McLearn, 1924, p. 66). The striae are flexuous in *C. novascotica* but straight in *C. melbournensis*. These two species are distinct, but closely approximate one another, and provide another interesting connecting link between the faunas of this age in North America and Australia. The spines of *C. striatella* are heavy and short and set at an angle of about 45° to the hinge-line, whereas those of *C. melbournensis* are long and slender and set at right angles to the hinge-line. The dorsal valve is definitely concave in *C. striatella*, whereas it is flat or almost so in *C. melbournensis*. *C. striatella* is characteristically larger and more transverse than the Victorian species. However, the obvious similarity is striking.

CHONETES (CHONETES) ROBUSTA Chapman.

(Pl. VIII., fig. 5.)

Chonetes robusta Chapman, 1903, pp. 76-77, pl. XII., fig. 8.

TYPE MATERIAL.—Two valves *in situ* (holotype), National Museum, Reg. No. 1417; about half of ventral valve, and most of dorsal valve, in indurated fine-grained sandstone from "North of Lilydale" (loc. 3, *vide* Gill, 1940, p. 258).

DESCRIPTION.—Concave-convex dorso-ventrally, 19 mm. wide (but this not full width as one cardinal angle broken), and 12 mm. long. Outline sub-semicircular. Shell tumid with mesial sinus and a slight flattening on the cardinal angles; longitudinal profile rises about 6 mm. above the plane joining the anterior and posterior margins of the shell. Hinge-line mostly absent, but little less than greatest width of shell owing to slightly obtuse cardinal angles. About thirty-six fairly sharp, high ribs (counted in middle of shell) some bifurcating anteriorly. Other specimens suggest that four strong spines on each side of the umbo (eight in all) is the normal number. The outer spine in the type specimen has a slight inclination outwards. The dorsal valve of the type specimen follows fairly closely the contours of the ventral valve, the greatest distance of separation being 1.5 mm. Similar ornamentation to that on the ventral valve is preserved. The ornamentation continues through to the interior of both valves. As is the case with practically all fossils from the Lilydale district, only casts and moulds are preserved, the original shell material having been leached away.

COMMENT.—The study of specimens other than the type shows that the beak is inconspicuous, scarcely projecting beyond the hinge-line; the cardinal area is flat and well-developed; median septum short and narrow; teeth and muscle scars not observed. The number of ribs has been noted to vary from 24 to 36. *C. robusta* is closely allied to *C. killarensis* sp. nov., and *C. cresswelli* Chapman.

Occurrence.—Besides the localities mentioned above, *C. robusta* is known from "Wilson's" (loc. 2), Hull-road, Mooroolbark (loc. 13), and Syme's Tunnel, Killara (loc. 34).

CHONETES (CHONETES) CRESSWELLI Chapman.

Chonetes cresswelli Chapman, 1903, pp. 77-78, pl. XII., fig. 7.

TYPE MATERIAL.—Internal cast of ventral valve (holotype) in indurated mudstone from "North of Lilydale" (National Museum, Reg. No. 652).

DESCRIPTION.—Shell approximately semi-circular in outline, being 7.5 mm. long and 13 mm. wide. Ventral valve convex rising about 3 mm. above the plane joining the anterior and

posterior margins. Beak inconspicuous, scarcely projecting beyond hinge-line. Hinge-line straight and nearly equal to greatest width of shell. Cardinal angles approximately right angles. Teeth fine. Short, fine median septum 1.5 mm. long. Very narrow cardinal area. Some 40 fine, rounded ribs radiate from umbo, bifurcations increasing number of ribs at margin to about 54. Other specimens show spines at right angles to the hinge-line; they are finer than those on *C. robusta*. Conspicuous mesial sinus present. Faint traces of concentric lines of growth observed. Spines on a specimen from Hull-road, Lilydale (loc. 1) are figured (Pl. VIII., fig. 5).

HORIZON.—Yeringian (Lower Devonian).

COMMENT.—This species is very closely related to *C. robusta*, the chief differences being (as Chapman remarked) in the altogether stouter build and fewer radii in *C. robusta*. The ribs are fine and rounded in *C. cresswelli* but high and sharp in *C. robusta*. Chapman also drew attention to the similarity between *C. cresswelli* and *C. australis* McCoy from the Middle Devonian rocks of Victoria. This is the more significant now in view of the much more closely approximated ages attributed to the Lilydale and Buchan Beds. *C. australis* occurs in great numbers in the Buchan and similar limestones, but no *Chonetes* has been found in the Cave Hill limestone beds at Lilydale. Brachiopods, except for *Atrypa reticularis*, are very rare at Cave Hill.

There is a close similarity between the chonetids of Victoria and those of the Devonian rocks of French Indochina. The Devonian of New Zealand, Eastern Australia, and Indochina appear to constitute a well-defined zone. Attention has already been directed to the similarity between certain trilobites in this zone (Gill, 1944). *Chonetes nongpoensis* (Mansuy, 1919, pp. 26-27, Plate V., fig. 4a, b) is very much like *C. cresswelli* Chapman. The general proportions of the shell are the same, the number of ornamenting ribs is about the same, and both have a well-marked mesial sinus, and short fine median septum. However, the ribs are rounded in *C. cresswelli* and raised and sharp in *C. nongpoensis*, as they are also in *C. robusta* which is a close variant of *C. cresswelli*. Unfortunately, the spines of *C. nongpoensis* are not known. As our knowledge stands at present, there is very little to separate *C. cresswelli* and *C. nongpoensis*. The specimens figured as *C. hardrensis* (Mansuy, 1921, Plate II., figs. 5a-c), *C. cf. margaritacea* (Mansuy, 1916a, Plate I., fig. 11), *C. indosinensis*, *C. lacroixi*, *C. lantenoisi*, and *C. cf. striatella* (Mansuy, 1916b, Plate VII., figs. 5-8), *C. zeili*, and *C. mansuyi* (Patte, 1926) are comparable with our Victorian types. It is interesting to note the presence of a mesial sinus on some of these forms, and the orientation of the spines at right angles to the hinge-line, as in our species. *C. lantenoisi* and *C. lacroixi* have the long median septum noted in *C. taggertyensis*.

CHONETES (CHONETES) AUSTRALIS McCoy.

Chonetes australis McCoy, 1876, p. 17, pl. XXXV., figs. 3-5.

Unfortunately, the National Museum is unable at present to locate the type specimen of *C. australis*. Further description of this form, and comment, are therefore withheld in the hope that the type may be found. As the specimen concerned is probably only misplaced and not really lost, it is not proposed to choose a lectotype.

Descriptions of New Species.

CHONETES (CHONETES) BOWIEAE, sp. nov.

(Pl. VIII., figs. 1 and 2.)

TYPE MATERIAL.—External cast and internal mould (syntypes) of a ventral valve in indurated fawn shale from Syme's Quarry, Killara, presented to the University of Melbourne, Geology Department Museum (counterparts, Reg. Nos. 1908-9). Collected by Mrs. R. Bowie, after whom the species is named.

DESCRIPTION.—Shell 17 mm. long (measured in one plane) and 19 mm. wide at the widest part; middle of the shell very tumid, but practically flat on the cardinal extremities. Cardinal angles obtuse. Hinge-line straight and less than greatest width of shell. Cardinal area flat, full width of hinge-line, parallel to plane of shell, and about 1 mm. wide. Eight long, evenly-spaced spines, fairly slender, project from the cardinal margin at right angles to the hinge-line; longest spine preserved is 7 mm. Beak projects a little beyond the hinge-line. Thin median septum about 4 mm. long, which is low at its anterior end where it rises from the floor of the shell, and becomes higher towards its posterior end. Interior of valve finely papillose around cardinal extremities; there are traces of papillosity elsewhere on the internal cast, which suggests that the whole interior of the valve was papillose. The type specimen is crushed slightly by lateral pressure. Teeth small and supported by dental lamellae almost parallel with the hinge-line. Between 50 and 60 fine rounded ribs (counted at the anterior margin) radiate from the umbo; increases by bifurcation.

HORIZON.—Yeringian (Lower Devonian).

COMMENT.—This species shares with *C. productoida* and *C. taggertyensis* general productid proportions. It provides a further link between the faunules of Lilydale and Killara. On the piece of rock containing the internal cast there is also a specimen of *Pleurodictyum megastomum* Dun, and on the piece containing the external mould a pygidium of *Lichas (Euarges) australis* McCoy, and *Beyrichia* sp. can be seen.

OCCURRENCE.—Syme's Quarry (loc. 35), Seville Quarry (loc. 37), Melbourne Hill, Lilydale (loc. 7), and doubtfully at Hull-road, Lilydale (loc. 1).

CHONETES (CHONETES) TAGGERTYENSIS, sp. nov.

(Pl. VIII., figs. 6 and 8.)

TYPE MATERIAL.—External cast and internal mould (syntypes) of a ventral valve in highly indurated fine-grained grey sandstone from Blue Hills, Taggerty, collected by Professor E. S. Hills and preserved in the University of Melbourne Geology Department Museum (counterparts, Reg. Nos. 1910, 1911).

DESCRIPTION.—Shell 22 to 24 mm. wide (one cardinal extremity is damaged and so an accurate measurement is not possible), 16 mm. long; profile rises 6 mm. above the plane joining the anterior and posterior margins. Valve very convex and flattened on the cardinal extremities ("oreillettes" of de Koninck). External mould shows 70 to 80 fine ribs at the anterior margin; increases by bifurcation. The ribs scarcely show on the internal cast except for a strip 3 to 4 mm. wide round the anterior perimeter of the shell. This is an area outside the phenomenally large muscle scars, and is finely papillate; slightly heavier papillae occur on the oreillettes. Large, flabellate, incised (i.e., raised in the mould) diductors extend three-quarters length of shell, enclosing incised adductors 4.5 mm. long. Beak inconspicuous, projecting just beyond the cardinal line. Cardinal area low at the extremities but rising to about 2 mm. in the centre—very high for *Chonetes*. Teeth very strong. Shell thick. Median septum strong and high at the cardinal end; at least 6.5 mm. long (between the cast and mould a little material has infiltrated and the septum may be longer than stated). There is the suggestion of a septum down almost the entire length of the shell. In the other specimen figured (Reg. No. 1912, paratype, Plate VIII., fig. 6), the septum is seen to run practically the whole length of the big adductor scars. No spines or spine bases can be distinguished on the type specimen, but in the associated specimen spine bases are present. The only difference between the type specimen and the other is that the latter is a little more transverse in proportions, and the muscle scars are a little more deeply incised. Both these variations are known to occur with increasing age in *Chonetes*.

HORIZON.—Probably Yeringian (Lower Devonian).

OCCURRENCE.—Blue Hills, Taggerty, Victoria. Professor Hills (1929) mentions the collection of *Chonetes* sp. from Taggerty, but the specimens figured herein were collected subsequently by him.

COMMENT.—*Chonetes taggertyensis* has a number of affinities with *C. sarcinulata* (Schlotheim) as figured by de Koninck (1847) in Pl. XX., fig. 15E. There the same flabellate, incised muscle

scars are seen with but faint trace of the ribs of the external ornament, a punctate margin is present showing more clearly the external ornament, and a very long median septum. The size of the muscles, the length of the septum, and the height of the ventral cardinal area are all phenomenal, and thus give more point to the comparison. However, the external ornament as described by de Koninck is quite different from that of our species, the ribs being many fewer in *C. sarcinulata*, practically all bifurcating, and doing so at about the same distance from the umbo. *C. sarcinulata* is one of the most characteristic fossils of the European Lower Devonian assemblage. *C. maoria* and *C. nigricans* (Allan, 1935; Shirley, 1938), from the New Zealand Lower Devonian, are of this same type, but the muscle area is smaller and the median septum shorter. However, a specimen of *C. maoria* in the National Museum, Melbourne, has a longer septum than that figured for the holotype. Allan says, "The general appearance of this species suggests such genera as *Plectambonites* Pander, but it probably belongs to *Chonetes*." The generic position of *C. maoria* is confirmed by the presence of one spine base and probably a second on the specimen in the National Museum, Melbourne. Like *C. sarcinulata*, the New Zealand species is highly papillose on the interior surface except on the muscle scars. From Allan's figure, it appears that *C. maoria* has a mesial sinus like *C. creswelli* and *C. robusta*. However, this is not present in the Melbourne specimen, nor is the "anterior margin somewhat sharply bent to produce a Leptaenid-like appearance." The latter may be due to pressure in the rock matrix.

C. taggertyensis is also like *C. unkelensis* (Dahmer, 1936, 1937), which is from the Siegenian of Unkel, and belongs to the *C. sarcinulata* gens.

CHONETES (CHONETES) PSILOPLIA, sp. nov.

(Pl. VIII, fig. 15.)

TYPE MATERIAL.—Holotype consisting of a ventral valve in bluish-grey mudstone from Killara collected by Mr. F. Chapman, and lodged in the National Museum, Melbourne (Reg. No. 14519). The fossil is probably from loc. 34 (Gill, 1944).

DESCRIPTION.—Valve 13 mm. wide, 6.5 mm. long, and height (distance profile rises above plane joining anterior and posterior margins) about 1.5 mm. The cardinal angles are approximately right angles so that the outline of the valve is not exactly semi-circular, but tends towards the sub-rectangular; the radius of the valve is 7.5 mm. half way between the cardinal angle and the centre of the posterior edge of the shell. Valve somewhat flattened on the cardinal extremities and round the perimeter, forming a marginal

flange comparable with that in *C. taggertyensis*. The muscle scars are not distinct, but inside the flange referred to there is a raised area on the cast where the ornament is less distinct and this may well be interpreted as incised muscle scars on the original shell. The external ornament consists of between 70 and 80 fine, somewhat sinuous, rounded ribs, increasing in number by bifurcation. Interior of valve finely papillate. Beak insignificant, not projecting beyond the hinge-line. Cardinal area about .5 mm. wide, smooth, and fairly regular in width. Two spines set at right angles to the hinge-line are preserved, but neither is complete; one fragment is .75 mm. long and the other 4 mm. These spines are very slender for a shell of this size—hence the trivial name. Impression of one tooth only (the other side is slightly broken away), and that is minute. Fine median septum 1.75 mm. long.

HORIZON.—Yeringian (Lower Devonian).

COMMENT.—This species is of the *C. sarcinulata* type with large incised muscle scars giving a differentiated margin to the interior of the ventral valve. The shell is of altogether lighter construction than *C. taggertyensis* (with which it may be compared), and the median septum is proportionately very much shorter. The spines are notable.

CHONETES (CHONETES) RUDDOCKENSIS, sp. nov.

(Pl. VIII., fig. 10.)

TYPE MATERIAL.—Holotype, consisting of an internal cast of a ventral valve in indurated olive-grey mudstone from Ruddock's Quarry (loc. 20), presented to the University of Melbourne Geology Department Museum (Reg. No. 1914).

DESCRIPTION.—Shell 7 mm. wide and 5.5 mm. long; longitudinal profile rises about 2 mm. above a line joining the anterior and posterior margins of the valve. Cardinal angles approximately right angles. Valve less convex on cardinal extremities. Beak insignificant. The two halves of the cardinal area form an angle of about 170°.

Ribs as seen in internal cast linear and of rounded cross-section; fine pitting between ribs, i.e., interior of valve finely papillose; about 40 ribs half way between anterior and posterior margins, and about 50 at the anterior margin; increase by bifurcation. What appears to be a linear median septum stretches nearly half way down the middle of the valve from the umbo. Cardinal area very narrow, and teeth not seen. Parts of two spines preserved on each side of the umbo; spines long and thin, set more or less at right angles to the hinge-line; longest spine present 3.5 mm.

HORIZON.—Yeringian (Lower Devonian).

OCCURRENCE.—In the Lilydale District the new species is known from Ruddock's Quarry (loc. 29, and from here the trivial name), Ruddock's Corner (loc. 21), Edward-road Hill (loc. 22), West of Lilydale Cemetery (loc. 23), Victoria-road cutting (loc. 24), "Devon Park" West (loc. 25), "Devon Park" North (loc. 26), North of Ruddock's (loc. 39), Manchester-road, Mooroolbark (large cutting north of station—a new locality), Smale's Farm (on the west side of Edward-road, north of Ruddock's—a new locality). It has also been collected from the Kinglake District from "near Strath Creek" by Professor E. S. Hills (Univ. Geol. Dept., Mus., Reg. No. 1916); a small *Pleurodictyum megastomum* is present on the same piece of rock.

COMMENT.—There is a good deal of variation in the group of shells at present included under *C. ruddockensis*. The type specimen is sub-quadrate in outline with 40 to 50 straight linear ribs. Another specimen noted is transverse in outline, with 30 to 40 stronger ribs which are somewhat sinuous. Intermediate stages between the type and this latter specimen have been observed. It is not clear yet how (if at all) this compact group should be subdivided, but a detailed study of a large collection will no doubt solve the problem. *Chonetes ruddockensis* has affinities with *C. setigera* Hall, which has similar proportions, ornament, and orientation of spines (at right angles to the hinge-line). Our species has fewer and different spines. Those of our species are remarkably long and slender, so much so that it is surprising that so many have been preserved. The waters in which the enclosing sediments were laid down must have been fairly quiet, an inference which may also be made from the fineness of those sediments. One shell from Ruddock's Quarry, 4.5 mm. long, has preserved a spine 8 mm. long, and it ends abruptly suggesting that it was even longer originally. In the European facies, *C. ruddockensis* seems to find its affinities with *C. soror* Barrande.

CHONETES (CHONETES) KILLARENSIS, sp. nov.

(Pl. VIII., fig. 14)

TYPE MATERIAL.—Internal cast of a ventral valve (holotype) in bluish-grey indurated mudstone from Syme's Tunnel, Killara (loc. 34), presented to the University of Melbourne Geology Department Museum (Reg. No. 1915).

DESCRIPTION.—Shell 20 mm. wide and 17 mm. long; evenly tumid except for mesial sinus and a slight flattening on the cardinal angles; longitudinal profile rises 5 mm. above the line joining the anterior and posterior margins of the shell. Mesial sulcus about 1 mm. deep, and about the width of five ribs. Cardinal angles approximately 115° . Cardinal area nearly straight, but the two halves of the line form a vertex at the umbo. Ribs

(on the internal cast) sharp and high, with bifurcations but no intercalations; number 34 half way between the anterior and the posterior margins, and 37 at the anterior margin; slight punctation between the ribs right in the cardinal angles. Probably ten very short, fine, somewhat sinuous spines ranged along the cardinal margin, perpendicular to the hinge-line; most complete spine present 1.5 mm. long. Cardinal area very narrow. Beak small, distinct, projecting slightly beyond the hinge-line. Median septum about 3 mm. long, not ending abruptly but tapering away on to the floor of the shell; septum about $1/6$ th mm. wide. Teeth strong.

HORIZON.—Yeringian (Lower Devonian).

COMMENT.—This new species is comparable with *C. robusta* which occurs in the same beds. The spines are long, straight, and strong in *C. robusta*, but short, fine, and sinuous in *C. killarensis*.

OCCURRENCE.—A form very similar to *C. killarensis* occurs in the soft fawn mudstones of Melbourne Hill, Lilydale (loc. 7). The spines are of the same kind, but the ribs are more numerous, and the mesial sinus very shallow. However, for the time being it is included in this species. In any case, the fossil constitutes another interesting link between the beds at Killara and those at Lilydale.

CHONETES (CHONETES) PRODUCTOIDA, sp. nov.

(Pl. VIII., figs. 7 and 12.)

TYPE MATERIAL.—Internal cast of a ventral valve (holotype) in indurated, fine-grained, fawn sandstone from Lilydale, Victoria. Collected by Reverend A. W. Cresswell, M.A., from "North of Lilydale" (loc. 3), and presented to the National Museum, Melbourne (Reg. No. 14520).

DESCRIPTION.—Length of shell (measured in one plane and not following obesity of shell) 17 mm., and width 21 mm.; longitudinal profile rises about 7 mm. above a line joining the anterior and posterior margins of the shell. Shell very tumid, but fairly flat on the cardinal margins, simulating productoid proportions—hence the trivial name. Cardinal angles damaged, but probably slightly obtuse. Hinge-line straight. Ribs (on internal cast) sharp and high, but have the appearance of being worn off on the anterior part of the type specimen (compare other figured specimen, National Museum, Reg. No. 14521—hypotype), number 31 half way between the anterior and posterior margins; increases by bifurcation. Umbonal area highly arched and overhangs hinge-line productid-fashion. The spine bases present indicate eight strong spines along the cardinal margin, probably

at right angles to the hinge-line. Cardinal area narrow. Median septum 3 mm. long, ending fairly abruptly; high, and about $\frac{1}{4}$ mm. wide. Teeth strong.

HORIZON.—Yeringian (Lower Devonian).

COMMENT.—This new species is very similar in external appearance to *C. hemispherica* Hall of the Upper Helderberg in North America, from which it can be distinguished readily by its fewer ribs. *C. productoida* is not merely the gerontic stage of *C. robusta* which also it closely resembles. Gerontic specimens of the latter are equally obese but do not have the high umbonal area and recurved beak of *C. productoida*. Moreover, *C. robusta* has a mesial sinus at all stages in its development, and the shell is not so flattened on the cardinal angles. It is interesting to note in this species (as also to certain extent in *C. bovicac*) the attainment of a *Productus*-like form.

CHONETES (CHONETES) GASKINI, sp. nov.

(Pl. VIII., fig. 9.)

TYPE MATERIAL.—A ventral valve preserved in hard, bluish limestone from the scarp along Old Hut Creek, Bindi District, Gippsland (see map, Gaskin, 1943). The species is named after Mr. A. J. Gaskin, who collected the type specimen, which is now in the University of Melbourne Geology Department Museum (Reg. No. 1913).

DESCRIPTION.—Ventral valve 4 cm. wide; greatest length preserved in type specimen (which is incomplete) 2 cm.; but a complete valve would be longer; height (distance profile rises above plane joining anterior and posterior margins) about 1.25 cm. Cardinal margin rises slightly at umbo, which is not prominent. One spine only preserved on the cardinal margin. It is $\frac{1}{2}$ cm. long, straight, slightly turned outwards, and possessing fine annulations (see photomicrograph, Pl. VIII., fig. 11). The valve is flattened on the cardinal extremities. The external ornament consists of 40 ribs which are much stronger in the centre of the shell than they are on the cardinal margins. The ribs do not all commence at the umbo, some beginning at locations along the cardinal margin, the furthest out starting at a point 13 mm. from the umbo. The ribs in cross-section form low arches, and the interspaces are about equal in width to the ribs.

HORIZON.—Bindi Limestone (Middle Devonian).

COMMENT.—This large new species is phenomenal for its possession of an annulated spine. It is clearly not an artefact, nor is it a small annulated shell like *Tentaculites* resting against the cardinal margin of the *Chonetes*. As far as the author is aware, an annulated spine on a *Chonetes* has not been described before.

Discussion of the Genus *Anoplia*.

Family CHONETIDAE Hall and Clarke, 1895.

Genus *Anoplia* Hall and Clarke, 1892.

Genoholotype 2. *Leptacna nucleata* Hall, 1857, 10th Rept. New York State Cabinet, p. 47 (quoted from *Fossilium Catalogus*).

ETYMOLOGY OF GENERIC NAME.—Greek *anoplos* = unarmed.

DIAGNOSIS OF GENUS.—Small chonetoids possessing a smooth or almost smooth surface, but without spines on the ventral cardinal margin. Ventral median septum, terminating abruptly.

COMMENT.—As far as the author is aware, only four species have been referred to this genus, viz.:—

Anoplia nucleata (Hall) Lower and Middle Devonian—Oriskany of Ontario and New York. Amazon. Onodaga and Grand Grève (Caley, 1940). Middle Devonian of Maryland. Lower Devonian of Moselle (Dahmer, 1928, 1930).

Anoplia heldbergiae Schuchert. Lower Devonian—Helderberg Formation.

Anoplia australis Gill. Lower Devonian of Victoria—Yeringian Series.

Anoplia withersi Gill. Ditto.

When Hall and Clarke erected the genus, the absence of spines was regarded as its chief feature—hence the name meaning “unarmed.” However, *A. heldbergiae* was found to possess spines like *Chonetes*, but Schuchert (1913) has argued that the genus is a good one to embrace “the early smooth or slightly lamellose, highly convex, small chonetoids with a ventral median septum.” The ventral median septum is a common feature of *Chonetes*, and the Victorian forms of *Anoplia* at least are not highly convex. Smooth *Chonetes* are also known. Thus, none of the features named by Schuchert can now be said to be characteristic of *Anoplia* alone. There seems to be no course left but to keep to the original definition of the genus as small, smooth chonetoids without spines, and refer *A. heldbergiae* to *Chonetes*. It is interesting to note that smooth forms have arisen twice in the *Chonetes* line of evolution, viz., *Anoplia* in the Lower Devonian, and smooth *Chonetes* (*C. glaber*) in the Upper Carboniferous.

Anoplia possesses reversionary characters. The term “reversion” is here used in distinction from the term “atavism,” and as defined by Crew (1925, p. 3). It may be assumed that the genus *Chonetes* “degenerated” in one direction to *Anoplia*, just as in another it “advanced” to *Productella* and *Productus*. The reversionary characters are:—

(1) Loss of ornament.—The surface of the shells is smooth in *Anoplia*, or almost so. Schuchert writes, “The smooth forms of *Chonetes* are not descendants of *Anoplia*, but are derived from

associated finely striated forms of the former genus." Apparently both the smooth *Chonetes* and *Anoplia* arose from finely striated *Chonetes* but at different times. Hall (1892, Plate 15a, fig. 18) figures a specimen of *A. nucleata* with faint ribbing which may be regarded as an indication of the ornament carried by its ancestors. An example of similar genetic interest is a specimen of *A. australis* collected by Mr. R. B. Withers in the Kinglake District (Plate VIII., fig. 4).

(2) Loss of Spines.—Hall and Clarke made this the chief diagnostic character of their genus, and it is indeed notable among a whole series of spinose forms which were an important element in marine faunas for over 150 million years. It is notable also for the reason that the general tendency with the effluxion of time was for the increase and not decrease of spinosity.

Notes on Species Previously Described.

ANOPLIA AUSTRALIS Gill.

Anoplia australis Gill, 1942, pp. 38-39, Pl. IV., fig. 8.

This species is very characteristic of the Ruddock's Quarry horizon of the type Yeringian Beds at Lilydale. It occurs in great numbers at Ruddock's Quarry along with equally great numbers of *Chonetes ruddockensis*, sp. nov., and *Stropheodonta bipartita* (Chapman). On the other hand, it is very rare in the highest beds of the series, only one specimen having been collected, for instance, from Hull-road, Mooroolbark. The Ruddock's Quarry horizon has been traced south to Mooroolbark, where *A. australis* has been collected from a large cutting on Manchester-road north of the railway station.

The two subsidiary ridges in addition to the median septum are of interest in this species. Certain parallels to these can be found in other genera. For example, *Sowerbyella gracilis* Jones (1928, p. 473, Plate XXIV., fig. 22) possesses a similar complement of ridges; also *Chonetes cumbrensis* Garwood (1931, p. 148).

Further Occurrences.—In addition to localities previously named, *A. australis* has been collected from the quarry north of Syme's Homestead, Killara (loc. 32), and from Jerusalem Creek (Geol. Surv. Vic., Reg. No. 18218).

ANOPLIA WITHERSI Gill.

Anoplia withersi Gill, 1942, p. 39, Pl. IV., fig. 7.

Usually *A. australis* is the dominant form where both the Victorian species are present together. An exception to this has been noted at Jerusalem Creek, east of Eildon Weir. The

numbers given with the following new records of occurrence are registered numbers of the Geological Survey of Victoria:—

Nos. 18222 and 18223—light fawny-grey sandstone from 70 chains S.E. of the junction of Jerusalem and Barnwell's Creeks, Jamieson, Q.S.

Nos. 18218 and 18227, from spur between Wilson's and Barnwell's Creeks.

Variations have been noticed in *A. withersi* in the length of the septa, in the prominence of the beak, and in the general outline of the shell.

Stratigraphical Considerations.

The earliest reference to chonetids in Victoria is probably that made by Blandowski in 1855 when he figured some undescribed fossils from the McIvor Goldfield. His plate opposite page 223, fig. 359, is evidently a *Chonetes*.

The named species of Victorian *Chonetes* were described by McCoy (1876) and Chapman (1903). To these the present writer has added two species of *Anoplia* (1942), and the new species of *Chonetes* described in this paper. These amount to fourteen chonetid species in all. Material has been collected which indicates the presence of a number of further new species, but the specimens are not good enough on which to found new species. The Silurian and Devonian rocks of Victoria are rich in chonetids. Some occur in gargantuan numbers, e.g., *Chonetes ruddockensis*, *C. australis*, and *Anoplia australis*; also to a less extent, *C. melbournensis*, *C. cresswelli*, and *A. withersi*.

SUBDIVISION OF THE YERINGIAN SERIES IN THE TYPE AREA.

The Victorian chonetids are good index fossils. *C. melbournensis* is strictly Melbournian, *C. australis* and *C. gaskini* strictly limited to the Buchan and Bindi Beds, and the rest strictly Yeringian (Lower Devonian). Divisions within the Yeringian Series can be satisfactorily made on the basis of these fossils, and the following subdivision is proposed (for structure, *vide* Gill, 1942):—

1. LOWER YERINGIAN—to be recognized by the presence of *Chonetes ruddockensis*, *Anoplia australis*, and *Stropheodonta bipartita*. (It has been noted that there is a *Stropheodonta bipartita* in the Devonian beds of North America (Swartz, 1941), but it belongs to *Leptostrophia*, which sub-genus is now accorded generic rank. As our *S. bipartita* belongs to *Stropheodonta sensu stricto* there is no need to change the name). These are all prolific forms, and their occurrence in strength may be always taken as an indication of the presence of this sub-division.

2. UPPER YERINGIAN—to be recognized by the presence of *Chonetes cresswelli*, *C. robusta*, and *C. killarensis*.

These subdivisions are in keeping with what we know of the Yeringian faunules as a whole. Of course, such subdivisions must be regarded as tentative in that further subdivisions will probably become possible as our knowledge of these beds and their faunules increases. However, this distinction between Upper and Lower Yeringian will help considerably in the classification of strata elsewhere in relation to the type Lilydale beds. For instance, the grey mudstone beds north of Tommy's Hut with plentiful *S. bipartita*, and the bluish indurated mudstones of West Kinglake with *A. australis*, the reddish mudstones of Yellingbo with *S. bipartita* and *C. cf. ruddockensis*, the grey mudstones at Christmas Hills with *S. bipartita*, and similar beds at "Two miles below Simmond's Bridge Hut on the Yarra," may all be classified as Lower Yeringian; the bluish-grey mudstones at Killara (locs. 34 and 35) may be classified as Upper Yeringian. The strong affinities between *C. taggertyensis* and the Upper Yeringian form *C. psiloplia* suggests an Upper Yeringian classification for the beds in the Blue Hills in which *C. taggertyensis* occurs. No *Chonetes* have yet been described from the Heathcote Beds, but the collections made by Dr. Thomas have not yet been studied.

Chonetes ruddockensis and *Stropheodonta bipartita* are entirely absent from the Upper Yeringian beds of the Lilydale District. One specimen only of *Anoplia australis* has been found at Hull-road, Mooroolbark (loc. 13), and one only at North of Lilydale (loc. 3), whereas both species are prolific in the Lower Yeringian. As far as our knowledge goes, any of the three forms named as characteristic of the Lower Yeringian, if present in strength, may be taken as indicative of a Lower Yeringian horizon. The three forms given as characteristic of the Upper Yeringian have not been found outside those beds, so apparently any of the three species, if present at all, is an indication of that horizon.

Ruddock's Quarry (loc. 20) is named as the type locality for the Lower Yeringian. The olive-grey indurated mudstones (with occasional still harder sandstone bands) found there can be traced from Mooroolbark through the Ruddock's Quarry area (where pitch affects the strike), and north towards Yarra Glen. Hull-road, Lilydale (loc. 1), is named as the type locality for the Upper Yeringian. There, in whitish and reddish soft mudstones, *C. robusta* and *C. cresswelli* have been collected, and *C. killarensis* occurs in the adjacent locality of Melbourne Hill, Lilydale (loc. 7).

THE JORDANIAN SERIES.—The next question is the relation of these forms to the Jordanian Series (Gill, 1941). Except for a few ubiquitous forms, the faunas of the Melbournian and

Yeringian are mutually exclusive, although they are both of littoral facies. There would not be this faunal break if the two series constituted a continuum in time. There must be a time-break between the two series, and this is occupied by the Jordanian Series. This series (as known at present) is pelagic, but not just the pelagic facies of a part of the Melbournian or Yeringian. Littoral forms are rare in the Jordanian, and so chonetids are not to be expected. A brachial valve which may be a *Chonetes* (collected by Dr. I. Cookson at McMahon's Creek) is the only chonetid found so far in the series.

The Melbournian beds contain graptolites of Lower Ludlow age (Jones, 1927). The Yeringian beds are Lower Devonian (Gill, 1942), and may even extend up into the Middle Devonian (Ripper, 1938, Hill, 1939, 1943). Thus there is a lacuna of Upper Ludlow age, which must be the age of the Jordanian beds. A *Posidonomya* common at McMahon's Creek (east of Warburton) is very similar to *P. eugyra* from étage E. of Bohemia, which is equivalent to the Upper Ludlow.

CORRELATION WITH OVERSEAS DEPOSITS.—There are interesting parallels between the Victorian chonetids and forms described from the classic series of Europe and North America; also from beds in Indochina. These may be summarized as follows:—

Stratigraphical position in Victoria.	Victorian Species.	Overseas Species.	Stratigraphical position Overseas.
Melbournian ..	<i>Chonetes melbournensis</i>	<i>C. novascotica</i> of Nth. America and Europe	Ludlow.
Yeringian ..	<i>C. productoida</i> ..	<i>C. hemispherica</i> of Nth. America. <i>C. verneuli</i> of Europe	Upper Helderberg, etc.
Yeringian ..	<i>C. cresswelli</i> ..	<i>C. mongpouensis</i> of Indochina	(Lower) Devonian
Yeringian ..	<i>C. ruddockensis</i> ..	<i>C. setigera</i> of Nth. America <i>C. soror</i> and <i>C. C. embryo</i> of Europe	Marcellus-Waverley
Yeringian ..	<i>C. taggertyensis</i> ..	<i>C. sarcinulata</i> ..	Lower Devonian, "most abundant in the Upper Siegenian."
		<i>C. unkelensis</i> ..	Uppermost L. Dev.
		<i>C. maoria</i> ..	Lower Devonian of N.Z., "Siegenian or Lower Coblenzian."
Yeringian ..	<i>Anoplia australis</i> ..	<i>A. nucleata</i> ..	L. Dev. of Moselle; Oriskany and Onondaga of Nth. America.

It should be noted that the above comparisons are not all of equal value. *C. melbournensis* and *C. novascotica* are very similar; so also are *C. taggertyensis*, *C. maoria*, and *C. sarcinulata*. On the other hand, the comparisons between *C. ruddockensis* and *C. setigera*, and between *C. productoida* and *C. hemispherica*, are based on striking likenesses in external form. In both the cases quoted the important internal characters are not known.

Further, there is no great likeness between our species of *Anophia* and *A. nucleata*, but as the genus is so rare in number of species, there is no doubt significance in its presence.

The Lilydale Beds, which constitute the type beds of the Yeringian Series, are very thick. Although the thickness already given on the evidence available (Gill, 1942) will very likely be reduced as our knowledge of the structure is increased, there nevertheless is certainly a great thickness of beds involved. It is possible that the mudstones and sandstones of the Yeringian Series cover the whole of Lower Devonian time, but a great thickness of beds below the Ruddock's Quarry horizon is apparently quite unfossiliferous, and the limits of the series have not yet been precisely defined. The writer prefers to wait till the faunules of the Yeringian type area have been further worked out, before drawing any close correlations with the classic overseas series.

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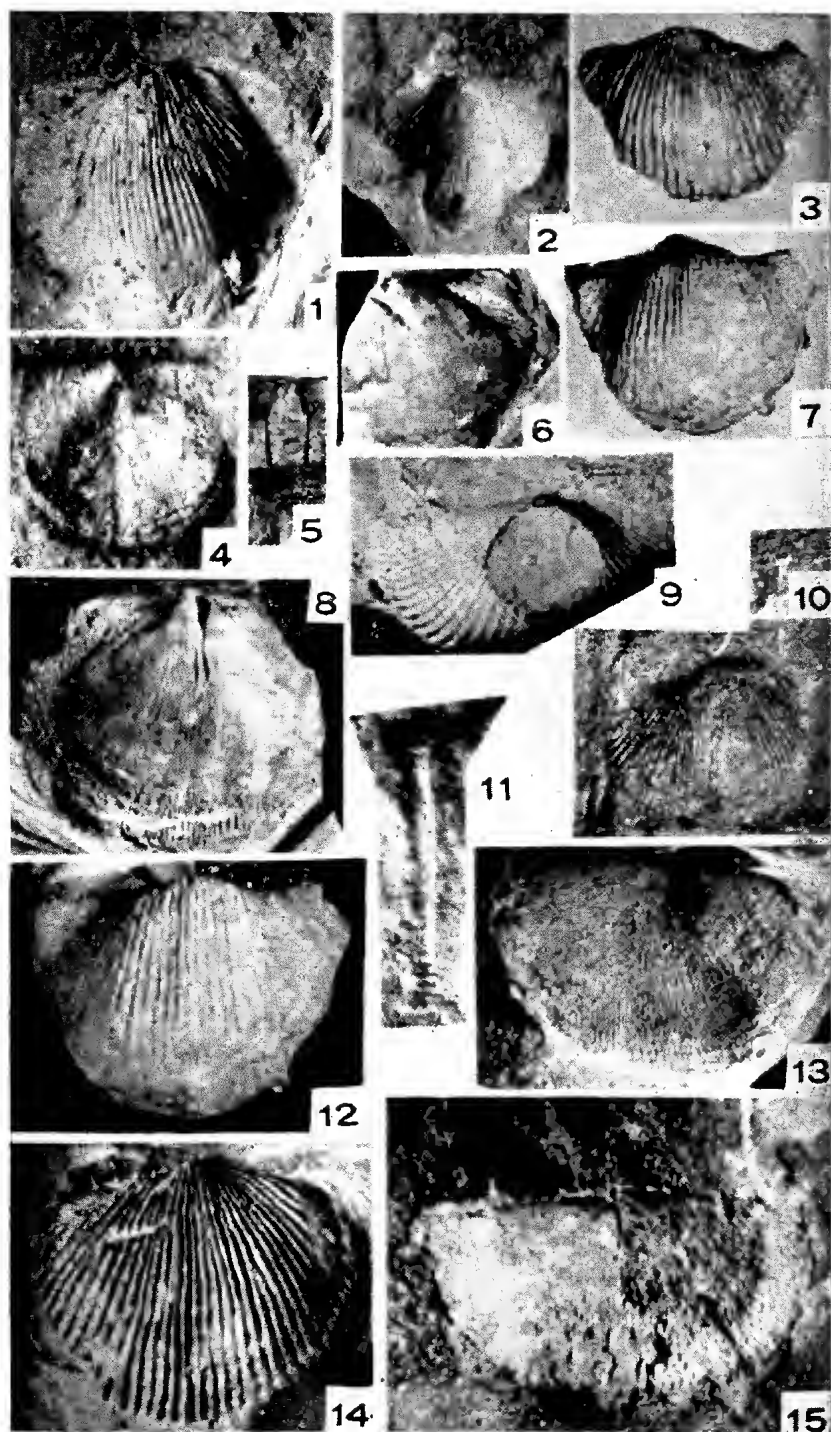
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Description of Plate.

PLATE VIII.

(No photographs are retouched.)

- FIG. 1.—*Chonetes bowiacae*, sp. nov., internal cast of ventral valve (syntype) $\times 2$ approx.
- FIG. 2.—*Chonetes bowiacae*, sp. nov., external mould of ventral valve (syntype) same size approx.
- FIG. 3.—*Chonetes productoida*, sp. nov., internal cast of ventral valve (hypotype) $\times 1.5$ approx.
- FIG. 4.—*Anobolia australis* Gill. Specimen from Kinglake showing ribbing (enlarged).
- FIG. 5.—Spines of *Chonetes cresswelli* Chapman. Specimen from Hull-road, Lilydale.
- FIG. 6.—*Chonetes taggartiensis*, sp. nov., internal cast of ventral valve (paratype) $\times 2$ approx.
- FIG. 7.—*Chonetes productoida*, sp. nov., internal cast of ventral valve (holotype) $\times 1.5$ approx.
- FIG. 8.—*Chonetes taggartiensis*, sp. nov., internal cast of ventral valve (syntype) $\times 2$ approx.
- FIG. 9.—*Chonetes gaskini*, sp. nov., ventral valve (holotype), same size. Note spine.
- FIG. 10.—*Chonetes ruddockensis*, sp. nov., internal cast of ventral valve (holotype) $\times 4$ approx. Note long spine.
- FIG. 11.—Photomicrograph of spine of *Chonetes gaskini*, sp. nov. (vide fig. 9). Note annulation where spine joins shell, and a series of annulations at the outer end.
- FIG. 12.—*Chonetes productoida*, sp. nov., internal cast of ventral valve (holotype) showing spine bases and medium septum.
- FIG. 13.—*Chonetes taggartiensis*, sp. nov., external mould (syntype) showing external ornament, $\times 2$ approx.
- FIG. 14.—*Chonetes killarensis*, sp. nov., internal cast of ventral valve (holotype) $\times 2$ approx.
- FIG. 15.—*Chonetes psiloplia*, sp. nov., internal cast of ventral valve (holotype) $\times 4$ approx.



Chonetes and Anoplia.

[PROC. ROY. SOC. VICTORIA, 57 (N.S.), PTS. I.-II., 1945.]

ART. VII.—*The Glauconitic Sandstone of the Tertiary of East Gippsland, Victoria.*

By A. B. EDWARDS.

[Read 14th December, 1944; issued separately 10th December, 1945.]

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Abstract.

The glauconitic sandstone formation that occurs at depth in the Tertiary strata of East Gippsland, Victoria, consists of grains of altered glauconite in a felspathic sandstone, which has a cement of glauconitic mud. The glauconite grains are largely derived from the alteration of biotite flakes. They often show open shrinkage cracks that developed at an early stage of lithification. Much of the glauconite is altered to a ferruginous clay-like substance. The alteration occurred during deposition, and prior to lithification, and is not a weathering effect, although it resembles the alteration of glauconite caused by weathering.

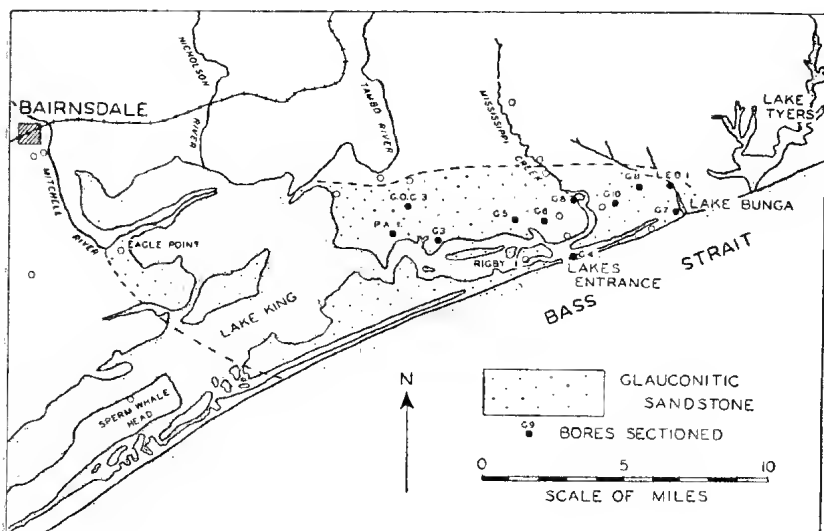
The air-dried rock shows abnormally high porosity, and low permeability. Impregnation of the rock with coloured canada balsam reveals that the natural cement of the rock is highly porous in an air-dried state, the pore spaces being of capillary dimensions. The high porosity appears to have been induced by air-drying of the rock, and may not be a feature of the rock *in situ*.

Introduction.

The petroliferous glauconitic sandstone that occurs in the Lakes Entrance district of Gippsland has been described briefly by Crespin (1943, p. 32). In this note it is proposed to elaborate several features of petrological interest exhibited by this rock.

The glauconitic sandstone occurs at or near the base of the Tertiary strata in this part of Victoria, above a bedrock of granitic and metamorphic rocks. In places it rests directly on

the bedrock, but mostly it is separated from it by a thickness of from 20 to 200 feet of Tertiary sediments. The glauconitic sandstone does not outcrop. Its limits have been defined by drilling (fig. 1). It extends from Lake Bunga in the east to Eagle's Point in the west, a distance of about 20 miles, and from the coastline northwards (inland) for a distance of from 3 to 5 miles. Its south-western limit is between Rigby Island and Sperm Whale Head. The sandstone is oil-bearing over an area of about 8 square miles in the vicinity of Lakes Entrance.



The glauconitic sandstone lies at a depth of from 960 to 1,416 feet below sea-level, the depth increasing towards the south or south-east at about 1 in 400. It has an average thickness of about 30 feet in the 40 bores that have intersected it. The maximum thickness recorded in any bore is 60 feet, in the No. 2 bore of the Lakes Entrance Development Co., near Lake Bunga in the parish of Colquhoun.

Crespin (1943) classifies the glauconitic sandstone as the lower lithological unit in the Janjukian stage of the Middle Miocene in Gippsland. It overlies Miocene strata of the Anglesean stage, and passes upwards into sandy micaceous marls which contain grains of glauconite in their lower beds.

A petrological examination of specimens from the core of the No. 10 Government bore at Lakes Entrance has been issued by Dr. F. L. Stillwell, under the title "Glauconitic Sandstone from

No. 10 bore, Lakes Entrance", as Mineragraphic Report No. 308, of the Council for Scientific and Industrial Research. This examination was made at the request of Dr. H. G. Raggatt, Director of the Mineral Resources Survey. Porosity measurements made by Mr. R. F. Thyer, of the Mineral Resources Survey, on dried specimens from this core had given porosities as high as 35 per cent., which is much in excess of that recorded for most oil sands, while permeability measurements on the same specimens had shown them to have low permeability. The petrological examination was sought in the hope that it might provide some explanation of this anomaly, but only a partial explanation was arrived at.

This, and other peculiar features of the glauconitic sandstone revealed by this examination, indicated that a more extensive petrological study of the formation as a whole was justified. To this end material from all the available cores of other Government and private bores was examined. This material was made available by the kindness of Mr. W. Baragwanath, then Director of the Geological Survey of Victoria.

My thanks are also due to Dr. M. Glaessner, Dr. W. D. Osborne, Mr. J. Montgomery, and Professor E. S. Hills, for helpful criticism of the manuscript. The original petrological examination (Mineragraphic Report No. 308) was made in collaboration with Dr. F. L. Stillwell.

Petrology.

In the hand specimen, the glauconitic sandstone is brownish-green to brown, and uniformly fine-grained, except for occasional rounded grains of iron-stained quartz, or quartzite, a millimetre or more in diameter. Occasionally these coarser grains are sufficiently numerous to give the rock a grit-like appearance over a thickness of about half an inch. A freshly broken surface is minutely pitted owing to the breaking out of the glauconite grains from the matrix. The grains that remain in the surface look like minute pellets of limonite. Some specimens contain sparsely distributed shells, such as *Turritelloids*, 1 to 2 cm. long. These are generally filled with glauconitic sandstone, though a very occasional shell may be only partly filled.

Thin sections were prepared of representative samples of the sandstone from the eleven available bore cores of the bores that have encountered this formation. They are Government bores Nos. 3, 4, 5, 6, 7, 8, 10, 11, and Lakes Entrance Development Co. No. 2 bore, all in the parish of Colquhoun, Point Addis Co. No. 1 bore, and Gippsland Oil Co. No. 3 bore, in the parish of

Bumberrah. These eleven bores are so spaced as to cover most of the extent of the glauconitic sandstone formation (fig. 1). From most of these cores, two samples some feet apart were sectioned, but from No. 10 Government bore, parish of Colquhoun, ten sections were cut, representing the horizons at 1,261-63 feet, 1,265-67 feet, 1,267-70 feet, 1,270-72 feet, 1,275-76 feet, 1,277-78 feet, 1,291-94 feet, and 1,294-1,300 feet. The close similarity between all the specimens sectioned leaves little doubt that they give a true picture of the composition of the sandstone formation.

Some of the bore cores had been air dried before they were received, others had been stored in sealed tins. Some had been drilled dry, and the drill cores were too hot to hold in the hand when raised; others had been drilled wet and were not heated unduly by the drilling. The differences in drilling practice and storage do not appear to have affected the state of the glauconite or the structures of the rock.

The specimens, with one exception, were too friable to section without previous impregnation. Since glauconite undergoes dehydration when heated above 70°C. (Ross, 1926; Takahishi, 1939), care was taken not to heat them unduly. The specimens were soaked in a thin, cold solution of canada balsam in xylol, and dried in an air oven at 30°C. The cemented material was then mounted and sectioned in the usual way. With some sections, it was necessary to coat the ground surface with the balsam-xylol solution and dry at 30°C. several times before a smooth surface suitable for mounting could be obtained; the same process had to be repeated during the final stages of grinding some of the thin sections. Wet specimens were dried for 24 hours at 30°C. in the air oven prior to impregnation.

The thin sections reveal that the specimens from the different bores, and from different horizons in the same bore, are closely similar in mineral composition and texture, but vary slightly in the proportion of the various constituents. They consist of numerous smooth-surfaced, oval and sub-angular grains of glauconite dispersed through a fine-grained feldspathic sandstone, which consists of quartz, orthoclase, oligoclase, and abundant biotite, with minor amounts of muscovite, pyrite, iron oxides, leucoxene, tourmaline, zircon, apatite, and in places a carbonate mineral, cemented together by a greenish to greenish-yellow isotropic substance, presumably a glauconitic mud. In some sections, this glauconitic mud is largely replaced by the carbonate mineral, which is presumably dolomitic, since it is not stained by treatment with silver nitrate and potassium chromate.

Occasional tests of foraminifera (consisting of calcite) are usually present, generally with a filling of green glauconitic material.

The quartz and felspar occur chiefly as angular to sub-angular grains from 0.1×0.1 mm. to 0.05×0.05 mm. in size; in some sections the majority of the grains are water worn. In addition, there is in every section a few coarser, limonite-coated and well-rounded fragments of quartzite, quartz or felspar, a millimetre or more in diameter, dispersed through the fine-grained rock. In some sections there are also occasional well-rounded pellets of fine-grained mudstone, more or less glauconitized, of about the same dimensions (Plate IX., fig. 7). These may be of coprolitic origin. Many of the numerous biotite flakes are slightly chloritized or glauconitized. They vary in size from 0.3×0.1 mm. to 0.1×0.05 mm.

These, together with the less common minerals, are set in an amorphous or cryptocrystalline greenish to yellowish substance which occurs as films of cement between the individual grains where they are closely packed (Plate IX, figs. 1 and 2), and as a base through which they are studded in sections in which they are widely spaced. In some sections the width of the green cement separating the individual grains is as much as 0.05 mm. The material appears to be a glauconitic mud, and generally forms the filling of the tests of foraminifera in the rock.

The proportion of carbonate varies greatly from section to section. In some it occurs only as the tests of the occasional shells and foraminifera, but in others it is an abundant constituent of the matrix of the rock, largely replacing the green base. In several of these sections, it occurs chiefly as well-formed and slightly iron-stained rhombohedra of dolomite about 0.05×0.03 mm., either as isolated crystals, or in clusters. This well-crystallized dolomite is presumably of diagenetic origin.

THE GLAUCONITE.

The glauconite grains are occasionally 1.0 mm. across, but are generally between 0.5×0.3 mm. and 0.2×0.2 mm. Some of the grains are green or greenish-yellow, but the majority of grains are yellow, yellowish-brown or reddish-brown, and some closely resemble limonite in appearance, indicating that they are altered forms of normal green glauconite comparable with the alteration products of glauconite described by Gildersleeves (1932) from the weathered Eocene greensands of Virginia and Maryland, U.S.A.

Some of the altered glauconite grains are zoned, the outer zone being generally darker than the core, though some show a narrow fringe of greenish-yellow material around the brown zones. In some sections a number of the grains have a green or greenish-yellow core with a yellow or brown margin.

Many of the grains have smooth, rounded surfaces, and some have a smooth, mammillated surface. Others are angular to sub-angular. Some of the rounded grains are nearly circular, but the majority are oval. Occasional grains contain inclusions of quartz that are finer-grained than the quartz of the sandstone.

Many of the glauconite grains reveal evidence of shrinkage. Sometimes the shrinkage cracks extend more or less radially into the grains (Plate IX., fig. 3). Many of the grains have shrunk away from the enclosing matrix (Plate IX., fig. 1) or from a narrow rim of glauconite strongly cemented to the matrix. Some zoned grains show shrinkage cracks at the margin of successive zones. These shrinkage cracks appear to be similar to the fractures in weathered glauconite figured by Gildersleeves (1932). For some grains, the shrinkage cracks may constitute as much as 30-40 per cent. by volume of the grain.

The shrinkage cracks are an original structure of the glauconite, and are not due to heating during drilling, or drying out of the specimens. This is proved by the fact that, in several sections, grains of altered glauconite occur in which shrinkage cracks have developed, but have been infilled with the green or greenish-yellow material that forms the cement between the grains of the sandstone (Plate IX., Fig. 2). The pattern of the shrinkage cracks (Plate IX., fig. 2) leaves little doubt that they arise from the drying out of an originally gelatinous substance. Similar shrinkage cracks, though not so strongly developed, characterize many grains of unaltered green glauconite found at higher horizons in the Gippsland bores.

The shrinkage probably occurred during lithification. Glauconite grains which have shrunk away from the enclosing matrix (Plate IX., fig. 1) or from a narrow rim of the grain strongly cemented to the matrix, could only have done so after the rock was more or less consolidated. Where the cracks have been infilled with glauconitic mud, either the shrinkage cracks occurred at an early stage of lithification and the glauconitic mud was squeezed into the opening or carried in by connate waters, or the glauconitic mud entered cracks which had developed during deposition. In sections with abundant carbonate, the carbonate rarely, if ever, occurs in the shrinkage cracks of the glauconite grains, though in such sections the cracks are often filled with green glauconitic

mud. Since the carbonate is probably diagenetic in origin, the filling of the shrinkage cracks, and hence their formation must have taken place either at an early stage of lithification or during deposition. The latter seems unlikely because the fractured parts of grains so broken by shrinkage cracks would readily have separated.

FORMATION OF THE GLAUCONITE.

As noted by Crespin (1943, p. 33), much of the glauconite appears to have formed from the alteration of biotite in the manner described by Galliher (1935). All stages of the transition from biotite to glauconite can be seen in the thin sections. The biotite first swelled in a direction at right angles to its cleavage planes. Commonly the swelling was greater on one side of the flake than on the other, so that the swollen flake became curved (Plate IX., fig. 4). Where this unequal swelling was pronounced, the biotite flake became fan-shaped, the cleavage traces corresponding to the ribs of the fan (Plate IX., fig. 5). In this expanded state, the biotite retains its pleochroism and colour. Takahashi (1939, p. 506) indicated that the swelling is caused by hydration of the biotite, which leaves it in a gelatinous state.

At this stage glauconite developed along the cleavage planes so that the biotite became parti-coloured brown lamellae alternating with green (fig. 8); the glauconite spread laterally into the biotite until the whole of the expanded flake was converted to glauconite, in which faint traces of the biotite cleavage still remain (Plate IX., fig. 6). During this transition, the lamellae of biotite between successive cleavage planes sometimes splayed apart, and when the splayed margins became slightly rounded, they gave the glauconite a mammillated outline (Plate IX., fig. 1) that might be mistaken for the cast of a foraminifera. As the gelatinous glauconite dried, it shrank, developing rounded edges and shrinkage cracks.

The well-rounded outlines of many of the glauconite grains, and of some of the expanded biotite flakes, contrast strongly with the distinctly angular form of many other grains of glauconite and expanded biotite (Plate IX., fig. 1). The rounding may be due to attrition during deposition or, more probably, as Galliher (1935) suggests, to passage through the intestines of worms while in a gelatinous condition.

The zoned character of some of these grains in their altered state is presumably due to the inward progression of alteration rather than to any original zonal structure on the glauconite grains.

The biotite flakes in their unaltered state are about 0.3 x 0.1 mm. or smaller. On expansion, the length of 0.3 mm. remains unchanged, but the width of 0.1 mm. increases to 0.5 mm. and occasionally even to 1.0 mm. This accounts for the distinctly larger grain size of the glauconite grains as compared with most of the other mineral constituents of the sandstone. Prior to the hydration of the biotite, and apart from the occasional, well-rounded, coarse grains of quartzite and pellets of mudstone, the detrital grains were well sorted. The size distribution of the grains appears to agree with that figured by Takahashi (1939, p. 511) for typical glauconite sandstones. The presence of the occasional, well-rounded, coarse grains is probably due to the fact that they would roll more readily under the action of relatively weak currents or wave movements than angular particles of the same size.

A small proportion of the glauconite grains have formed not from biotite but by the impregnation with glauconite of the mudstone pellets that occur sparsely through the rocks. The grains so derived can be distinguished even when highly altered, because they contain inclusions of small fragments of quartz, distinctly smaller than most of the quartz grains in the groundmass (Plate IX., fig. 8).

ALTERATION OF THE GLAUCONITE.

The alteration of the glauconite occurred either prior to or during lithification. In some sections (Bore No. 5, parish of Colquhoun) normal green and altered brown glauconite, with all intermediate stages, occur in the same section. The altered glauconite grains are sometimes rimmed by a thin margin of greenish glauconite, and the shrinkage cracks in the altered glauconite are filled with green or greenish-yellow glauconite mud.

A small, relatively pure sample of the altered glauconite containing some adherent quartz, was prepared by crushing the rock from No. 10 Government bore, parish of Colquhoun, with a rolling pin so as not to break the glauconite grains unduly, and then separating the glauconite from the bulk of the other minerals in the rock by suspension in bromoform of Specific Gravity 2.85. The glauconite-rich product obtained was then screened through a 60-mesh sieve. The material retained on the sieve consisted essentially of glauconite grains with a little adhering quartz. An analysis of this sample gave the composition shown in Table 1, Analysis No. 1. For glauconite to alter to a substance of this composition, the silica, potash and soda of the original mineral (compare Analyses Nos. 3 and 4) must have been replaced extensively by ferric oxide. Most observers (Collet and Lee,

1905; Cayeux, 1916; Milner, 1940), agree that glauconite is an unstable mineral which readily alters to limonite or ferruginous clay if exposed to oxidising conditions, so that this is a normal change for glauconite to undergo.

Such a change could have been brought about by weathering, by the action of iron-bearing solutions during lithification, or during deposition. The films of oxide on the occasional coarse, rounded grains of quartzite might be regarded as evidence of the passage of oxidizing iron-bearing water through the rock, but weathering or alteration during lithification seem to be ruled out because the green glauconitic mud that forms the cement of the rock, and fills the shrinkage cracks in the altered grains, is generally unaltered. The association of grains of green and brown glauconite in the same section, and the relatively unoxidized state of the pyrite grains in the rock, is further evidence supporting this conclusion. The fact that there is no concentration of alteration along the margins of shrinkage cracks shows that the alteration took place prior to shrinkage and while the material was still gelatinous.

TABLE 1.—COMPOSITION OF ALTERED AND NORMAL GLAUCONITE.

	1	2	3	4
SiO ₂	25.81	27.74	53.61	49.47
Al ₂ O ₃	7.27	13.02	9.56	5.59
Fe ₂ O ₃	47.25	39.93	21.46	19.46
FeO	0.72	1.76	1.58	3.36
MgO	2.14	4.62	2.87	3.96
CaO	2.00	1.19	1.39	0.60
K ₂ O	2.31	0.95	3.49	8.04
Na ₂ O	nil	0.62	0.42	0.16
H ₂ O	11.89	10.85	5.96	8.54
CO ₂	tr.	—	—	0.56
TiO ₂	0.05	—	—	—
MnO	0.05	—	tr.	—
P ₂ O ₅	0.35	—	—	1.06
<i>Total</i>	99.84	100.68	100.34	100.80

1. Altered glauconite (with some quartz) from the Miocene glauconite sandstone, Bore No. 10, parish of Colquhoun, Gippsland. *Analyst:* A. B. Edwards.
2. Decomposed glauconite, from recent marine deposits (quoted by Collet and Lee, *Proc. Roy. Soc. Edin.*, 1905, vol. 26, pp. 238-278), from Murray and Renard, *Deep Sea Deposits*, Challenger Report, 1891).
3. Average of four analyses of recent glauconites collected by the Challenger expedition (Twenhofel, *Treatise on Sedimentation*, 1932, p. 456).
4. Purified glauconite from Cretaceous of New Jersey (*Ibid.*).

It seems probable, therefore, that this glauconite was altered to limonite or ferruginous clay during its deposition. Glauconite forming in the present oceans is sometimes subject to just such alteration, under conditions that are not yet defined (Collet and Lee, 1905). Comparison of Analysis No. 2 of Table 1 with Analysis No. 1 shows how closely such altered glauconite in deep sea deposits now forming can resemble the altered glauconite of this Miocene sandstone.

Collet and Lee have also shown that a brown ferruginous clay develops as a midstage in the formation of glauconite from pellets of grey clay, the green colour of the glauconite appearing only when potassium is introduced into the ferruginous clay. While this might apply to the brown glauconite developed from the mudstone pellets, it cannot be true for most of the altered glauconite, which was formed from biotite, because Galliher (1935) found no trace of such an intermediate stage in present-day glauconite forming directly from biotite.

PERMEABILITY AND POROSITY.

The permeability of the glauconitic sandstone was first measured by Croll (1939) who used material from the No. 1 Government bore, parish of Colquhoun, the No. 2 bore of the Lakes Entrance Development Co., and the No. 1 Kalinna bore. He obtained an average permeability of 223 millidarcies along the bedding, and of 15 millidarcies across the bedding. Individual measurements ranged from 5 millidarcies to 450 millidarcies. Thyer's unpublished measurements for the No. 10 bore indicate a lower permeability, with no consistent difference in directions parallel to and transverse to the bedding.

The appearance of the glauconitic sandstone in thin section throws little light on the variable permeability, and fails to account for the unusually high porosity of the dried rock. A piece of the air-dried core of No. 11 bore, parish of Colquhoun, was ground to a block measuring 7.5 x 6.0 x 6.0 cm. This was immersed in distilled water. Innumerable minute bubbles developed on the surface of the block, and showed only a very slight enlargement in size, until they escaped from the surface after one or more days, without other bubbles forming in their place. From three or four points, however, strong persistent streams of minute bubbles issued, several hundred bubbles being emitted per minute by each stream. These streams of bubbles continued for about two and a half hours. The bubbles from two such streams were trapped in inverted test tubes filled with water, from which it was found that the volumes of air emitted by the bubble streams amounted to 8 c.c. for one stream and nearly 10 c.c. for the other.

This feature of the emission of persistent streams of bubbles at one or two points was noted in practically all the specimens immersed in xylol-canada balsam solutions. In some instances, air from connected channelways issued at two points on the same specimen, and filling of the pores with solution led to the sudden cessation of one stream of bubbles, with a simultaneous increased emission in the other stream. This, coupled with the practical absence of bubble emission over large areas of the specimens, indicates that the larger open spaces in the rock tend to be localized, and so explains the great variability in permeability noted by Croll and Thyer. It was also noted, in the case of the large block of rock referred to above, that the bubble streams issued from faces at right angles to the bedding of the rock, rather than from faces parallel to the bedding, suggesting that, as Croll found, there may in some specimens be a somewhat greater permeability parallel to the bedding than across it.

The absorption ratio of this block of rock, after immersion for seven days, followed by drying for six hours at 105°C., and for a further three days in a sulphuric acid dessicator at room temperatures, was 17·8 per cent. Repetition gave a practically identical result. The specific gravity of the powdered rock from which the block was cut was 1·8, so that the apparent porosity of the block was approximately 32 per cent., which is of the same order as Thyer's more accurate measurements.

The absorption ratios measured in the same way on air-dried specimens from three other bore cores, namely No. 5 bore (1,238·43 feet), No. 8 bore (1,055 feet), and No. 10 bore (1,270·72 feet) were 10·5 per cent., 16·5 per cent., and 17·2 per cent. respectively, corresponding to apparent porosities of about 18 per cent., 29 per cent., and 31 per cent.

These high absorption ratios may be a measure of the pore space of the rock, or they may represent the capacity of the glauconitic mud cement to absorb water. If they measure the pore space of the rock, then since there are no obvious cavities or open spaces of this volume present, then such pore space can be accounted for only as due either to incomplete compaction allowing the existence of submicroscopic openings along the grain boundaries and in the glauconitic mud cement, or to air-drying of the rock inducing such openings in the cement.

To test this, specimens of the glauconitic sandstone were impregnated with a bright red xylol-balsam solution, so that the distribution of the balsam absorbed by the rock could be traced in thin section. The balsam was intensely coloured by means of an oil-soluble red dye, which is manufactured by British Drug

Houses, and is soluble in xylol. On evaporating out the xylol from the xylol-balsam solution on a hot plate, and heating the balsam until it set hard, the balsam retained the dye, though remaining perfectly transparent, and the colour remained fast. In thin sections the coloured balsam appeared pink.

A series of sections were prepared from air-dried material impregnated with this red balsam from the cores of the No. 4, No. 6, No. 8, and No. 10 bores. The thin sections revealed only a few actual fractures, grain boundaries, or natural open spaces filled with pink balsam, and more often than not the shrinkage cracks in the grains of altered glauconite remained unfilled. The cement of glauconitic mud, however, was changed in colour from green or yellowish-green to a pinkish-brown, indicating that the dyed xylol-balsam solution had penetrated it more or less uniformly, presumably along submicroscopic openings. The pinkish colour was not due to reaction with the glauconitic mud cement, because over a period of about seven days the glauconitic mud cement slowly resumed its normal greenish colour, possibly as a result of slow oxidation of the dye-stuff, or of base exchange between it and the dye-stuff. It is concluded from this that the glauconitic mud forming the natural cement of the rock is highly porous in its air-dried state, the pore being chiefly capillary openings, with diameters between 0.001 mm. and 0.0002 mm. The natural cement commonly constitutes 50 per cent. or more of the rock, so that if it were highly porous, such openings could account for much or all of the measured porosity.

It seems highly doubtful, however, that this measured porosity is the true porosity of the rock in its natural state, because even air-drying of the rock might cause a shrinkage of the natural cement and increase the porosity of the rock considerably.

Conclusion.

Glauconite can form from a variety of substances, provided that they become gelatinous through hydration (Takahashi, 1939, pp. 506-512). Such substances include faecal pellets, clay, colloidal and opaline silica, sponge spicules, fragments of volcanic glass, and minerals such as feldspars, pyroxenes and micas. Which of these substances will be the dominant source in any one locality will depend partly on the mineral composition of the rocks from which the sedimentary materials are derived, and partly upon their relative susceptibility to hydration and gelatinization, other factors being equal.

Thus, in areas like that under consideration, where the sedimentary material was derived largely from granitic rocks, the substances most susceptible to glauconitization that will be

present in abundance are biotite and felspar. The observations of Galliher (1935) and those described above show that in such circumstances biotite becomes hydrated and gelatinous much more readily than the associated felspars, so that the biotite tends to be altered to glauconite while the felspar remains fresh and unaltered.

The alteration of glauconite to ferruginous clay or limonite follows the same general course, whether the alteration takes place during deposition, during diagenesis, or subsequently as a result of weathering. Altered glauconite is not, therefore, of itself sufficient evidence of a disconformity in a sedimentary series.

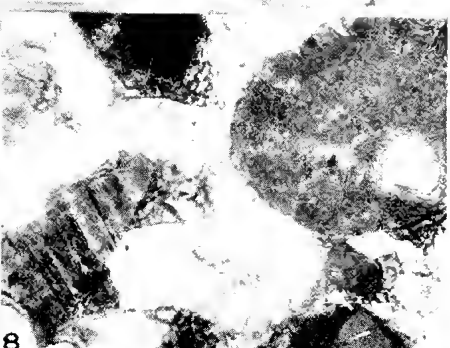
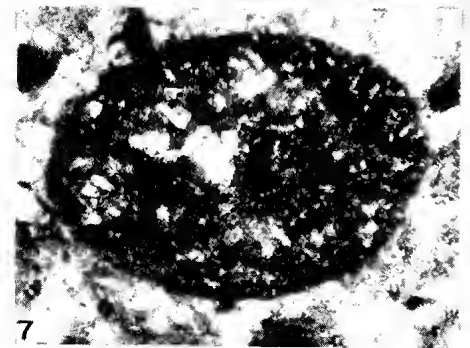
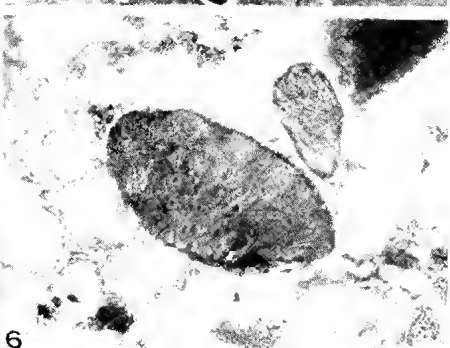
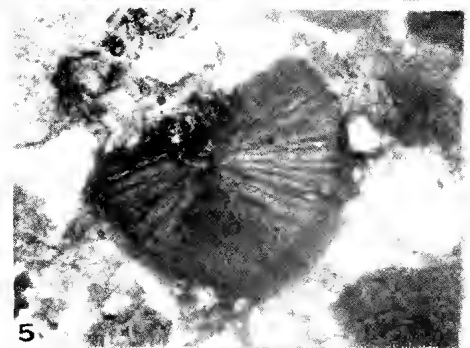
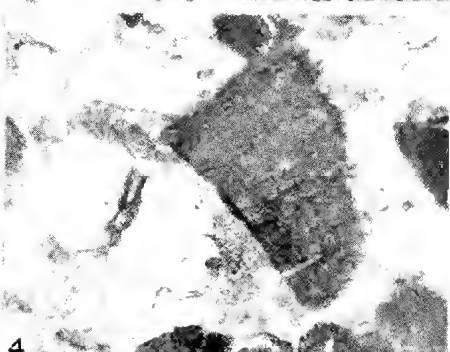
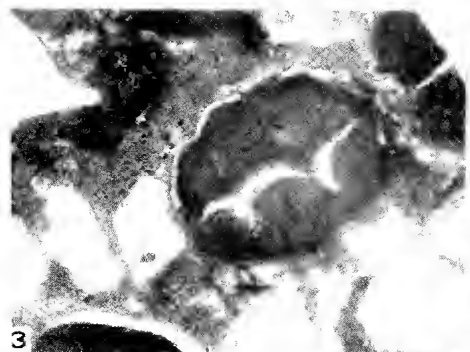
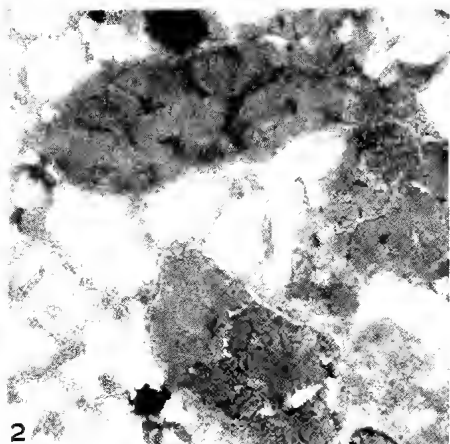
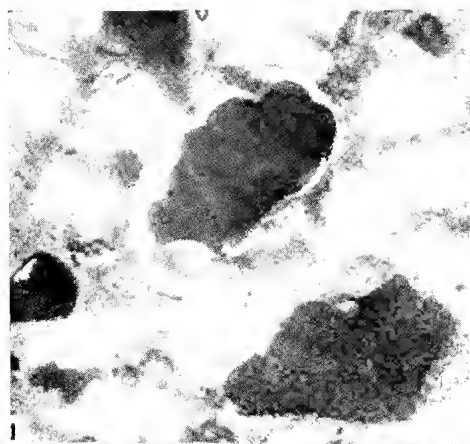
It is also clear that the appearance of a rock in thin section is not always a reliable guide as to its porosity, and that special techniques, such as impregnating the rock with coloured media, are necessary to determine the nature of the open spaces. Moreover, in dealing with rocks which contain a considerable proportion of clays or clay-like substances, any drying of the rock may cause considerable shrinkage of such substances so that porosity measurements on such dried rock will not be a measure of the porosity of the rock in its natural state.

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Description of Plate.**PLATE IX.**

- FIG. 1.—Oval grain of altered glauconite which has shrunk away from the enclosing matrix. The protuberances and indentations on the edge of the altered glauconite match similar fractures on the edge of the matrix, indicating that the void has not been caused by the grinding of the rock section. Below it is a sub-angular grain of altered glauconite. Ordinary light. $\times 100$.
- FIG. 2.—Oval and bean-shaped grains of altered glauconite showing pattern of shrinkage cracks filled by unaltered glauconite material similar to that forming the cement of the matrix of the rock. Ordinary light. $\times 100$.
- FIG. 3.—Oval grain of altered glauconite with internal shrinkage cracks. $\times 100$.
- FIG. 4.—Curved grain of expanded biotite unequally swollen in the direction at right-angles to the cleavage planes. Ordinary light. $\times 100$.
- FIG. 5.—Fan-shaped grain of expanded biotite. Ordinary light. $\times 100$.
- FIG. 6.—Grain of partly altered glauconite, showing traces of cleavage planes of original biotite. $\times 100$.
- FIG. 7.—Oval pellet of mudstone, containing minute inclusions of quartz. $\times 75$.
- FIG. 8.—Part of oval grain of altered glauconite on right, with enclosed grain of quartz smaller than quartz in matrix; and irregular flake of expanded biotite partly replaced along cleavages by green glauconite. $\times 100$.



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Hutchinson, R. C., B.Sc., Dept. of Agriculture, Rabaul	1939
Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7	1913
Jacobson, R., M.Sc., 41 Thanet-street, Malvern, S.E.4	1937
Jessep, A. W., B.Sc., M.Ag.Sc., Botanical Gardens, Sth. Yarra, S.E.1	1927
Jona, J. Leon, M.D., M.S., D.Sc., Lister House, 61 Collins-street, Melbourne, C.1	1914
Kenny, J. P. L., B.C.E., Mines Department, Public Offices, C.2 ..	1942
Kilvington, T., M.Sc., Physiology Department, University, N.3 ..	1938

Langham, Miss Beryl, B.Sc., 8 Myrtle-road, Hampton, S.7	..	1945
McCance, D., M.Sc., 144 Gatehouse-street, Parkville, N.2	..	1931
McLennan, Assoc. Prof. Ethel, D.Sc., University, Carlton, N.3	..	1915
Macpherson, Miss J. Hope, National Museum, Melbourne	..	1940
Manning, N., 16 Fairmont-avenue, Camberwell, E.6	..	1940
Melhuish, T. D'A., M.Sc., c/o Elliots & Aust. Drug Pty. Ltd., Terry-street, Rozelle, N.S.W.	..	1919
Morris, P. F., National Herbarium, South Yarra, S.E.1	..	1922
Moy, A. F., Melbourne Boys High School, Prospect Hill-road, Canterbury, E.7.	..	1943
Mushin, Mrs. Rose, 150 Garton-street, North Carlton, N.4	..	1940
Newman, B. W., B.Sc., Meteorological Bureau, Sydney	..	1927
Nye, E. E., College of Pharmacy, 360 Swanston-street, Melbourne, C.1	..	1932
Oke, C., 34 Bourke-street, Melbourne, C.1	..	1922
Osborne, N., 35 Dorrington-avenue, Glen Iris, S.E.6	..	1930
Pinches, Mrs. M., 8 Thomas-street, Brunswick, N.10	..	1943
Prentice, H. J., B.Sc., Higher Elementary School, Wodonga	..	1936
Pretty, R. B., M.Sc., Technical School, Wonthaggi, Vic.	..	1922
Raff, Miss J. W., M.Sc., F.R.E.S., University, Carlton, N.3	..	1910
Rayment, Tarlton, Bath-street, Sandringham, S.8	..	1929
Richardson, Sidney C., 16 Brewster-street, Essendon, W.5	..	1923
Samson, H. R., B.Sc., 34 Park-street, Parkville, N.2	..	1945
Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3	..	1924
Scott, T. R., M.Sc., B.Ed., 27 Currajong-avenue, Camberwell, E.6	..	1934
Shaw, Dr. C. Gordon, 57 Clendon-road, Toorak, S.E.2	..	1931
Sherrard, Mrs. H. M., M.Sc., 43 Robertson-road, Centennial Park, N.S.W.	..	1918
Singleton, O. P., 126 Anderson-street, South Yarra, S.E.1	..	1943
Stach, L. W., M.Sc., 250 Riversdale-road, Hawthorn, E.3	..	1932
Stubbs, G. C., Plant Laboratory, Burnley, E.1	..	1943
Thomas, G. A., B.Sc., National Museum, Melbourne	..	1944
Thomas, L. A., B.Sc., c/o Council for Scientific and Industrial Research, Stanthorpe, Queensland	..	1930
Trüdinger, W., 27 Gerald-street, Murrumbidgee, S.E.9	..	1918
Tubb, J. A., M.Sc., Fisheries Section, C.S.I.R., Cronulla, N.S.W.	..	1936
Vasey, A. J., B.Agr.Sc., Animal Health Laboratory, Parkville, N.3	..	1937
Vasey, G. H., B.C.E., University, Carlton, N.3	..	1936
Wade, G. C., B.Agr.Sc., Plant Research Laboratory, Swan-street, Burnley, E.1	..	1941
Whincup, Mrs. Sylvia, B.Sc., Kerang	..	1942
Wilcock, A. A., B.Sc., B.Ed., 21 Park-road, Maryborough	..	1934
Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5	..	1921
Wood, Prof. G. L., M.A., Litt. D., University, Carlton, N.3	..	1933
Woodburn, Mrs. Fenton, 21 Bayview-crescent, Black Rock, S.9	..	1930
Wunderly, J., D.D.Sc. (Melb.), 7 Victoria-road, Camberwell, E.6	..	1937

Royal Society of Victoria.

ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR 1944

The Council presents to members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1944. The following meetings of the Society were held:

March 9: Annual Meeting. The following office-bearers were elected: President, Mr. W. Baragwanath; Vice-Presidents, Major D. A. Casey, Captain J. K. Davis; Honorary Treasurer, Mr. W. J. Parr; Honorary Librarian, Mr. F. A. Cudmore; Honorary Secretary, Dr. F. L. Stillwell; Members of Council, Professor E. W. Skeats, Professor S. M. Wadham, Professor R. D. Wright, Dr. R. T. Patton, Mr. D. J. Mahony, Mr. Crosbie Morrison.

The following members of Council continued in office: Professor W. A. Osborne, Professor H. S. Summers, Professor J. S. Turner, Dr. J. M. Baldwin, Mr. J. S. Rogers, Associate-Professor O. W. Tiegs.

The Annual Report and the Financial Statement for 1943 were read and adopted.

At the close of the Annual Meeting an Ordinary Meeting was held. Lecture: "Flax and Flax Production," by Dr. I. F. Phipps.

April 13: Lecture: "The Electron Microscope," by Dr. J. S. Hosking.

May 11: Lecture: "The Road to Darwin with the Army Education Services in Northern Australia," by P. Crosbie Morrison.

June 15: Lecture: "The Meteorological Conditions of Gliding," by Dr. F. Loewe.

July 13: Papers: "Classification of Victorian Plant Communities," by Dr. R. T. Patton. "The Stratigraphical Range and Habitat of the Diprotodontidae in South-East Australia," by R. A. Keble. "Note on Some Buried Valleys along the South Gippsland Coast," by Dr. A. B. Edwards. "Geology of Phillip Island," by Dr. A. B. Edwards.

August 10: Lecture: "Some Borderlands of Microbiology, Biochemistry and Genetics," by Dr. F. M. Burnet.

September 14: Lecture: "Sheep and Wool: Recent Research and Prospective Developments," by Professor A. F. Barker.

October 12: Lecture: "The Problem of the Origin of Insects," by Associate-Professor O. W. Tiegs.

November 9: Papers: "Note on the Age and Palaeogeography of the Brown Coal Deposits of Gippsland, Victoria," by Irene Crespin. "Australian Ambrosia Fungi," by Mrs. Shirley Webb. Lecture: "The Leigh Creek Coalfield," by Dr. A. B. Edwards.

December 14: Papers: "Botrytis Corn Rot of the Gladiolus—Its Cause and Control," by G. C. Wade. "A Glauconitic Sandstone from the Tertiary of East Gippsland," by Dr. A. B. Edwards. "The Chonetidae of the Palaeozoic Rocks of Victoria," by Rev. E. D. Gill. "A Commentary on a Recent Classification of the Gippsland Tertiary," by Dr. F. A. Singleton. "Tertiary (Janjukian) Shelly Faunules from near Princetown, Victoria," by Dr. F. A. Singleton and Owen P. Singleton.

The Society's Hall was still required by the Army Hiring Department under the National Security Regulations for Defence purposes, but satisfactory arrangements continued for its use by the Society for the monthly meetings.

Reciprocal arrangements have been made with the Royal Societies in other States whereby members, visiting another State, may attend meetings and use the library of the Royal Society in that State on production of a letter from the Secretary of this Society. The privileges are available for three months, and may be extended at the discretion of the Council of the local Society.

During the year, two members, two country members and three associate members were elected.

The Council deeply regrets the loss by death of three life members, one member, one country member and two associate members.

Thomas Ranken Lyle, Kt., M.A., D.Sc., F.R.S., Emeritus Professor of Natural Philosophy of the University of Melbourne, was born in 1860 in Coleraine, Northern Ireland, and educated at the Coleraine Academic Institute and Trinity College, Dublin. He graduated with high academic distinctions, which were combined with athletic prowess. His first post was lecturer in mathematics at the Catholic College, Dublin, and he was a member of the Irish International Rugby Football teams of 1885-7. In 1889, he was appointed Professor of Natural Philosophy in the University of Melbourne, holding the chair until his retirement in 1915. In 1905, he was awarded the D.Sc. of Dublin University and, in 1912, he was elected F.R.S. After relinquishing his Chair, he was associated with H. J. Grayson at the University of Melbourne in the production of diffraction gratings, and, after Grayson's death, purchased the machine from Grayson's estate. Just before his death he donated this machine to the National Standards Laboratory of Australia. Lyle carried a load of important public responsibilities, being rewarded with a knighthood in 1922. He was the first Chairman of the State Electricity Commission and afterwards continued as a member. He was chairman of the Board of Visitors at the Melbourne Observatory from 1903, a member and Vice-President of the Council of Education. He was a

director of the Metropolitan Gas Co., a member of the Federal Munitions Committee set up during the 1914-18 war, a chairman of the Industries Exemption Committee and first chairman of the Standards Association of Australia. Lyle's published contributions to science lie mainly in the domain of electrical circuit theory. He was the first to give a complete theory of the simple alternator, and he was among the first in Australia to take X-ray photographs, using tubes made with his own hands. He contributed articles on related subjects to the Proceedings of this Society in 1904-5. He was elected a member of the Society in 1889 and an honorary life-member in 1938. He died on March 31 at the age of eighty-three.

Ambrose Pratt was born at Forbes, N.S.W., in 1874, and educated at the Sydney Grammar School and Sydney University, graduating in law in 1896. Within a few years he retired from the legal profession and went to England, published several novels and entered the field of journalism. Returning to Australia in 1904, he became a leader writer on the "Age." In 1915 he became editor and part proprietor of the Australian Industrial and Mining Standard, retiring from journalism in 1927. He then became company director to several tin dredging companies in Malaya and Thailand. Apart from his newspaper work, he wrote about 30 novels, as well as several zoological, economic and historical works. His interests were wide and he was for many years President of the Royal Zoological and Acclimatisation Society of Victoria, a member of the committee of the library Association and a vice-president of the League of Youth Movement. He was also a member of the Board of Management of Mount Royal Hospital and Queen's Memorial Hospital. He was elected a member of this Society in 1918 and became a life member in 1933. He died on September 13 at the age of 70 years.

Daniel James Mahony, M.Sc., was born in 1878 at Melbourne, and graduated as a bachelor of science at the University of Melbourne in 1904. In 1906 he joined the Geological Survey of Victoria as petrologist. In 1912 he was locum tenens for Sir Douglas Mawson at the Adelaide University during the Australasian Antarctic Expedition. He served with the Royal Artillery in the war of 1914-1918. In 1931 he was transferred from the Geological Survey of Victoria to the post of Director of the National Museum. In this capacity he introduced the dioramas and staged a fitting setting of the famous ethnological collection. In doing so, Mr. Mahony contributed generously from his own pocket and secured substantial donations from some of his friends. He helped to form the Galleries and Museums Association of Australia, of which he was the first chairman. He was a chairman of the scientific committee of the Zoological Board of Victoria. He joined this Society in 1901, and served as a member of Council from 1931 till his death, being President 1939-1940. He contributed two papers on Tertiary Volcanic Rocks to the Proceedings of the Society. He died on September 28 shortly after his retirement from the Museum.

Gilbert Rigg was born in England in 1873. He commenced his association with zinc production in 1906, when he was appointed chief of the research department of the New Jersey Zinc Co., U.S.A., and in the last five years of his engagement he also held the position of sales engineer. In 1916, he came to Australia as metallurgical engineer to the Broken Hill Associated Smelters Pty. Ltd., and, at the same time, he became consulting metallurgical engineer to the Electrolytic Zinc Co. of Australasia Ltd. In 1924, jointly with Herbert Gepp, he was awarded the Gold Medal of the Institution of Mining and Metallurgy, London, in recognition of joint and individual achievements in the development of the electrolytic process for the production of zinc, and in the treatment of complex sulphide ores in Australia. After 1926, he retired from active professional life though still retaining his connection with the Broken Hill Associated Smelters as consultant. He then devoted himself more and more to his own private researches, maintaining a keen interest in those scientific developments which particularly interested him. He was elected a member of this Society in 1931. He died on September 2.

Herbert Montgomerie Standish Cox, of Wombat Park, Daylesford, pastoralist, died on March 14, 1944, aged 85. He was born at Rawdon Station, Rylston, N.S.W., and was a famous horseman in his younger days. He was a grandson of Captain William Cox who organised and carried out the construction of the first road from Sydney across the Blue Mountains, which was completed in 1815, eighteen months after it was begun. He was elected a country member of this Society in 1931.

John George Easton joined the Mines Department in 1897, and first served as assistant on geological surveys in the Snowy River, the Apollo Bay-Forrest and the Baw Baw-Aberfeldy districts and on a detailed survey of the Berringa mines. In 1904, he was appointed to take charge of a survey of the Myrtleford auriferous belt, which was subsequently extended to include the Buckland River, Buffalo Creek, Stanley and Twist's Creek areas. He was next engaged in mapping large areas in the northern portion of Benambra and, from 1923-35, with his headquarters at Bairnsdale, he conducted a geological and topographical survey of considerably more than 500 square miles of Eastern Gippsland. He retired in 1942, but was immediately engaged by the Commonwealth Government to supervise the boring for bauxite in Gippsland. In 1943, he was re-employed by the Mines Department as curator of the Geological Museum, and held this post until his death on August 9, 1944. He was elected an associate member of the Society in 1913, and contributed a paper as joint author with Dr. A. B. Edwards on the "Igneous Rocks of North-Eastern Benambra" to the Proceedings of this Society.

John Cuthbert Traill was born at Geelong in 1864 and educated at Geelong Grammar School and Melbourne University.

He was one of the earliest students of Ormond College and graduated B.A., B.C.E., in 1888. He then joined the staff of Huddart Parker Ltd., of which his father was one of the founders. He was at one time manager of the Geelong office and was transferred later to Melbourne. He maintained a wide interest in cultural matters and was president of the Old Ormond Students' Association in 1923-4. He was elected an associate member of this Society in 1903. He died on August 21 at the age of eighty.

The attendances at the Council meetings were as follows: Mr. Baragwanath, 10; Mr. Morrison, 10; Mr. Parr, 10; Dr. Patton, 10; Dr. Baldwin, 9; Mr. Cudmore, 9; Professor Skeats, 8; Dr. Stillwell, 8; Associate Professor Tiegs, 8; Captain Davis, 7; Professor Summers, 7; Mr. Rogers, 5; Professor Turner, 5; Professor Wadham, 5; Mr. Mahony, 4; Professor Osborne, 0; Professor Wright, 0. Major D. A. Casey was granted leave of absence for military duties.

During the year, 831 volumes and parts were added to the library. Many of the overseas exchanges are temporarily suspended on account of the war. Owing to man-power difficulties arising from the war, the Hon. Librarian has carried on without the help of an assistant librarian. Members are asked to co-operate by returning borrowed books within the specified time limit of three months. The value of the library has proved itself in the war effort. Books have been lent to Australian, American and Dutch Forces, also to departments and firms on war work, while the Society is co-operating in the compilation, by the Allied Geographical Section, of an Annotated Bibliography of the Southwest Pacific and Adjacent Areas.

Volume 56, Part 1, of the Proceedings of the Society was issued on August 1. The publication of this volume was assisted by a credit of £100 made available at the Government Printing Office by the State Government, and by grants from the University Publications Fund, towards the cost of publishing papers from the Science Departments of the University of Melbourne.

HONORARY TREASURER'S REPORT.

The financial statement shows a credit balance of £371/10/9 at 31st December, 1944, as against £194/12/2 at the end of the previous year. This balance does not, however, represent the true position, as, because of delays in printing, the second part of Volume 56 of the Proceedings was not published during the year, and this expenditure, estimated at £230, has yet to be met.

Subscriptions have been well maintained, but the falling off in the total general receipts other than rents has continued. Rents have increased as a result of the temporary occupation of part of the Hall by the R.A.A.F. Without the receipts from this source the financial position of the Society would be deteriorating because of the greatly increased cost of printing the Proceedings.

Financial Statement for Year ending December 31st, 1944.

RECEIPTS.		EXPENDITURE.	
Balance in Bank at 1/1/44	...	£194 12 2	...
Subscriptions—			
Members	£107 2 0		£204 12 6
Associate Members	68 4 6		28 16 10
Country Members	11 11 0		...
Arrears paid up	59 6 6		...
Advance Subscriptions	4 14 6		£233 9 4
Rents—		250 18 6	
Comwealth Government	£100 0 0		24 0 0
R.A.F. ...	156 0 0		10 0 0
Field Naturalists' Club...	16 0 0		12 0 0
Microscopical Society	9 0 0		26 7 6
Sale of Publications	...	281 0 0	72 7 6
Interest on Bonds	...	19 0 10	10 10 6
Grants and Donations—	...	14 5 0	11 2 3 6
Government of Vict.	£100 0 0		14 6 8
Univ. of Melbourne	40 0 0		5 1 3
Surplus Cash	...	140 0 0	10 16 2
			12 18 4
			34 17 3
			6 18 3
			4 15 4
			100 0 0
			8 16 5
			2 7 0
			371 10 9
			£899 17 0

W. J. PARR, Hon. Treasurer.

Audited and found correct,

31st January, 1945.

WILFRID N. KERNOT } *Hon.*
T. M. CHERRY, } *Auditors.*

SPECIAL FUNDS.

HALL FUND.

Balance at 1/1/44	...	...	£61 3 4	Balance at 31/12/44	...	...	£62 7 9
Interest to 31/5/44	...	...	1 4 5				
			<u>£62 7 9</u>				<u>£62 7 9</u>

LIFE MEMBERSHIP FUND.

Balance at 1/1/44	...	...	£94 9 2	Balance at 31/12/44	...	...	£96 4 10
Interest to 31/5/44	...	...	1 15 8				
			<u>£96 4 10</u>				<u>£96 4 10</u>

HOWITT MEMORIAL FUND.

Balance at 1/1/44	...	...	£88 2 0	Balance at 31/12/44	...	...	£93 14 2
Interest on Bond	...	...	3 17 6				
Savings Bank Interest to 31/5/44	...	...	1 14 8				
			<u>£93 14 2</u>				<u>£93 14 2</u>

SPECIAL FUNDS (continued)

T. S. HALL MEMORIAL FUND.					
Balance at 1/1/44	...	...	£69 18 7	Balance at 31/12/44	...
Interest to 31/5/44	..	...	1 7 7	...	£71 6 2
			£71 6 2		£71 6 2

Accounts and Pass-books relating to each of the above Funds have been severally examined and found correct, and the Bank certificate of possession of Bonds amounting to Five Hundred Pounds (£500) and War Savings Certificates to the face value of One Hundred and Twentyfive Pounds (£125) has also been inspected.

W. J. PARR, *Hon. Treasurer.*


31st January, 1945

WILFRID N. KERNOT } *Hon.*
T. M. CHERRY } *Auditors.*


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